

Instrument Report

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**INSTRUMENTS FOR THE STANFORD
UNIVERSITY/STANFORD RESEARCH INSTITUTE
VLF EXPERIMENT (4917) ON THE EOGO SATELLITE**

By: L. H. RORDEN L. E. ORSAK B. P. FICKLIN R. H. STEHLE

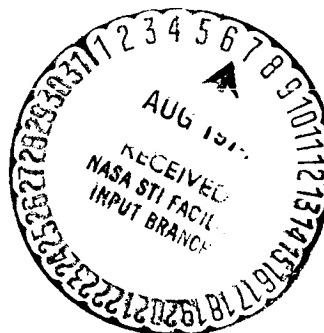
Prepared for:

STANFORD UNIVERSITY
STANFORD, CALIFORNIA

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SRI Project 4007

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1. INTRODUCTION

1.1 APPLICATION AND DESCRIPTION

The report describes a receiver designed and constructed to perform an experiment aboard the NASA OGO-A (S-49) and OGO-B (S-49A) satellites (Fig. 1.1). The joint Stanford University/Stanford Research Institute VLF experiment is intended not only to verify ground observation by direct measurement in the magnetosphere but also to explore the VLF electromagnetic environment beyond the magnetosphere.

The satellite instrument is designed to accomplish the following three main scientific goals:

- (1) Compile a comprehensive survey of VLF noise of natural origin found within the region of the orbit. The phenomena may be classified into the following categories:
 - (a) Terrestrial noise produced below a height of 70 km, such as atmospherics due to lightning
 - (b) Noise generated within the earth's ionosphere and magnetosphere, such as VLF emissions produced by charged particles trapped in the earth's magnetic field
 - (c) Cosmic noise of extraterrestrial origin, such as solar and planetary noise.

This survey is expected to be instrumental in determining the sources of various VLF phenomena observed on the ground and in other satellite and rocket experiments.

- (2) Extend the understanding of VLF propagation in the ionosphere. This should, in turn, increase our knowledge of the composition of the upper atmosphere, since the propagation of the VLF waves is extremely sensitive to the low levels of ionization and magnetic field found there. Both natural and artificial sources will be used in propagation measurements, by employing techniques developed at Stanford University and Stanford Research Institute in previous rocket and satellite experiments.

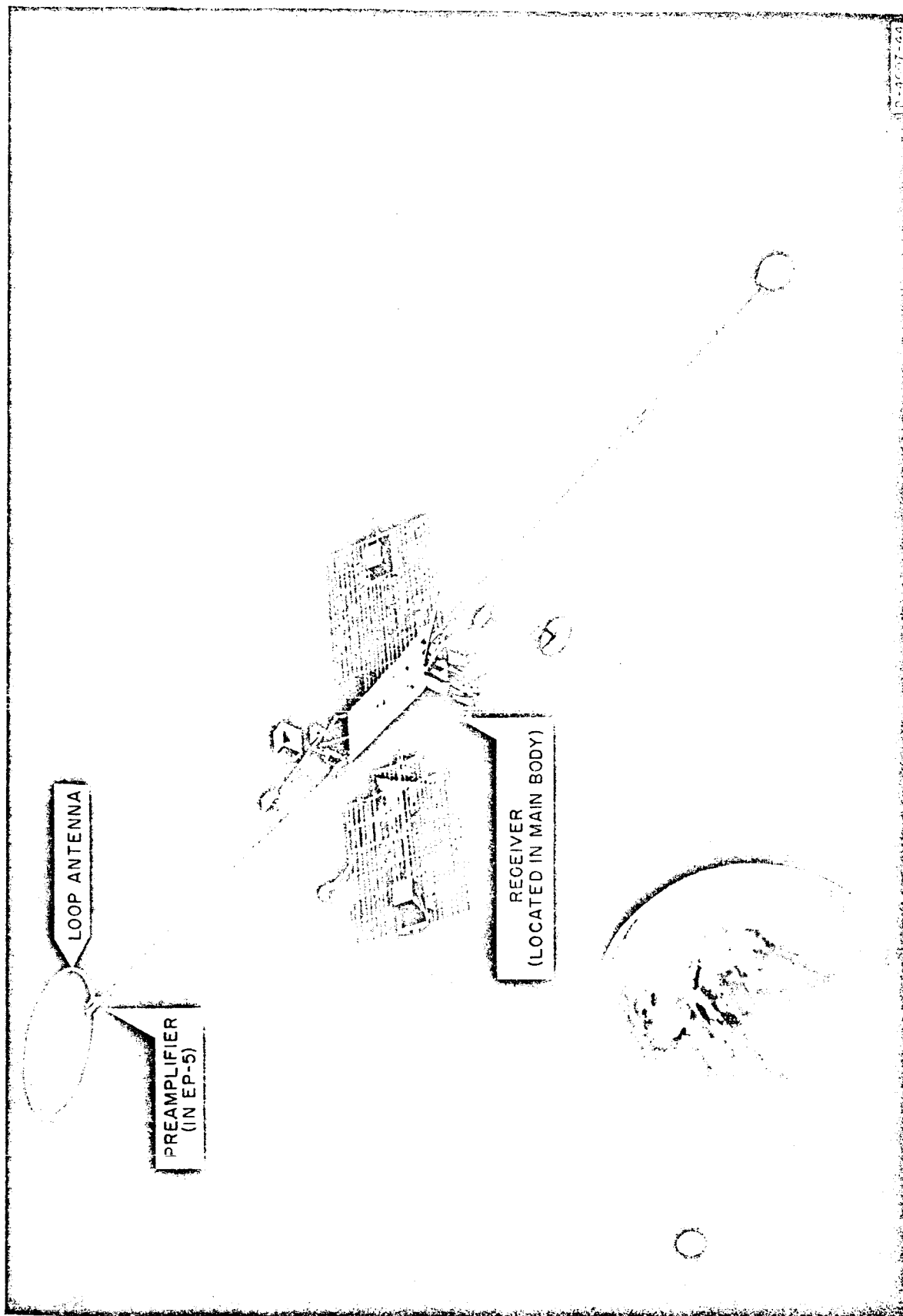


FIG. 1.1 S-49 SATELLITE

- (3) Compile engineering information that will improve the design of instrumentation for subsequent experiments. This will include evaluations of sensitivity, frequency range, resolution, dynamic range, stability, etc., to determine what modifications of these parameters would improve the experiment.

Since the measurements undertaken by the EOGO VLF receiver are exploratory in nature, the receiver is designed to provide a wide range of measurement capability and to have appreciable versatility. This includes wide frequency coverage (0.2-100-kHz contiguous narrow-band measurements and 0.2-12.5-kHz broadband measurements), large dynamic range (approximately 80 dB), both swept-frequency and fixed-frequency operation of the narrow-band receivers, and capability of relative phase measurements on ground transmitters. These capabilities must, of course, be accomplished within the constraints of available weight, size, power, data transmission, and ground command capability provided by the satellite. To meet these goals, significant development of improved receiver circuitry suitable for reliable satellite operation resulted in a receiver that exceeded the original requirements of weight, size, and power; made efficient use of satellite data capability and ground commands; and yet provided VLF measurement capability not previously obtained.

1.2 FUNCTIONAL DESCRIPTION

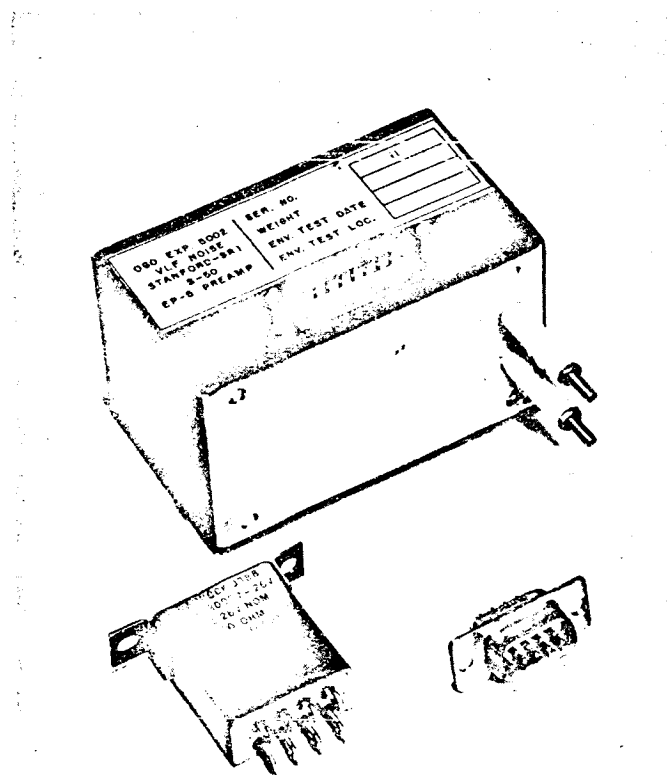
The EOGO VLF receiver consists of two major parts:

- (1) An antenna and preamplifier at the end of a long boom, and
- (2) The receiver electronics package located in the satellite main body.

The antenna is a torus, 2.9-m in diameter with a 7.6-cm diameter cross section, fabricated from aluminum-Mylar laminate in the form of an inflatable tube (see Fig. 1.1). The antenna was designed and built by the Antennas and Microwave department of Lockheed Missiles and Space Company under subcontract to Stanford University. The deflated antenna is stowed in a small volume during launch and is inflated in orbit by ground command after the long boom is deployed. The loop antenna is

connected to the preamplifier terminals by two wires, which also form a small loop with approximately 0.1 m^2 of included area; this loop serves as a backup for the large loop.

The preamplifier (Fig. 1.2) is a broadband low-noise amplifier covering the frequency range 0.2 to 100 kHz with noise temperature of approximately 50°K . The matching network between antenna and preamplifier includes a transformer to match the antenna impedance to the amplifier and to provide circuits for injecting a calibrate current in shunt with the antenna and a calibrate voltage in series with the antenna. These injections provide calibration of the receiver and, in addition, are used to measure the antenna impedance. Sufficient gain is provided by the preamplifier so that satellite interference signals picked up in the preamplifier output cables and thermal noise in the receiver input

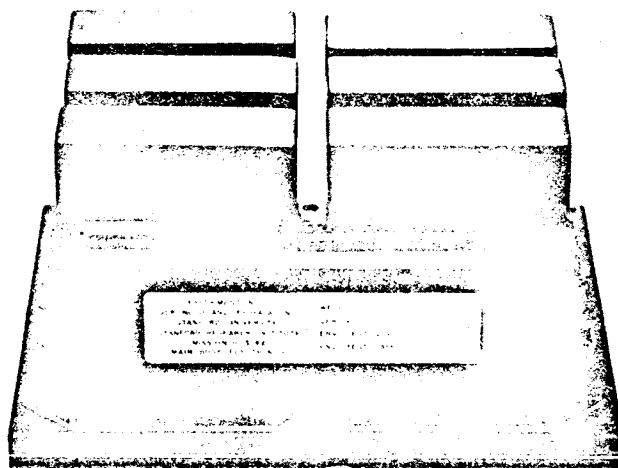


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FIG. 1.2 PREAMPLIFIER ASSEMBLY

circuits are negligible compared to interference signals received directly by the antenna and the thermal noise of the preamplifier, respectively.

The receiver (Fig. 1.3), consists of three narrow-band receivers that simultaneously cover the bands 0.2 to 1.6 kHz, 1.6 to 12.5 kHz, and 12.5 to 100 kHz in 256 equal frequency steps. In addition, a broadband receiver



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FIG. 1.3 RECEIVER ASSEMBLY

gives outputs of broadband spectrum and average amplitude of signals in the 0.3-to-12.5 kHz range. Various modes of operating these receivers are provided by a command memory operating from ground command. These modes include, in some combination, the following:

- (1) Automatic stepping of the narrow-band receivers in synchronism with the spacecraft digital data system, with digital data from each receiver output
- (2) Stepping of the narrow-band receivers by ground command to any desired signal with digital data from each receiver output, and analog data on the amplitude and relative phase of the output of the 12.5-to-100 kHz receiver

- (3) Average amplitude, with $BW \approx 300$ Hz, and broadband spectrum of the output of the broadband receiver (0.3 to 12.5 kHz)
- (4) Injection of combination of current and voltage calibrate signals into the antenna circuit every 16th frequency sweep of the narrow-band receivers.

The narrow-band and broadband receiver amplitude outputs are logarithmic functions of input signal with a 20-dB range of output voltage representing signals from approximately receiver threshold to 80 dB above receiver threshold.

1.3 SUMMARY OF TECHNICAL CHARACTERISTICS

Table 1.1 summarizes the characteristics of the receiver.

Table 1.1
SUMMARY OF TECHNICAL CHARACTERISTICS

<u>Dimensions:</u>	Main-Body Package	19.0 X 15.5 X 9.2 cm
	Preamplifier	4.7 X 4.7 X 7.8 cm
	Antenna (furled)	13 X 22 X 9 cm
	Antenna (unfurled)	2.9-m dia. torus of 7.6-cm dia. thin-wall Mylar-aluminum tube
	Antenna Inflation Mechanism	
	Gas Bottle	5 X 12 cm (dia. X length)
	Actuator	6.4 X 4.4 X 2.2 cm
	Relief Valve	2 X 2 X 6 cm
<u>Weight:</u>	Main-Body Package	800 g
	Preamplifier	130 g
	Antenna	315 g
	Antenna Inflation Mechanism	
	Gas Bottle	320 g
	Actuator	115 g
	Relief Valve	45 g
	Gas (2000 psi Argon)	20 g
<u>Input Power:</u> 28.5 \pm 5.0 Vdc, 33 mA		

Receiver Characteristics:

Parameter	Band 1	Band 2	Band 3	Broadband
Freq. Range (kHz)	0.2-1.6	1.6-12.5	12.5-100	0.3-12.5
Threshold Sensitivity (γ)	$2.4-0.3 \times 10^{-4}$	$2.4-0.3 \times 10^{-5}$	$16-2 \times 10^{-7}$	$3 \times 10^{-2}-3 \times 10^{-5}$
Dynamic Range (dB)	90	90	80	80
Analog Output (V)	0-5	0-5	0-5	- - -
LO Freq. (kHz)	3.11-1.71	24.9-14.0	199.5-112	
IF Freq. (kHz)	3.31	26.5	212	- - -
BW, -3 dB (Hz)	40	160	600	- - -
BW, -60 dB (Hz)	450	1300	4500	- - -
ΔF /step (Hz)	5.4	43	344	- - -
Data Rate (kb/s)	<u>1,8,64</u>	<u>1,8,64</u>	<u>1,8,64</u>	- - -
Sweep Rate (steps/s)	1.68,13.9,111	1.68,13.9,111	1.68,13.9,111	- - -
Sweep Time (s)	147,18.4,2.3	147,18.4,2.3	147,18.4,2.3	- - -
Output TC (ms)	880,110,14	340,49,4.4	150,18,2	- - -

The sweep receivers are automatically stepped (with characteristics given) whenever the receiver is in Mode 1 and 2; in Mode 3 the receivers can be stepped by ground command to any desired frequency. One command will step the receivers one step, a different command will step the receiver eight steps.

Data Outputs and Receiver Modes: See Table 1.2.

Antenna Temperature Monitor:

The temperature at the antenna manifold is monitored by a sensor with temperature range of approximately -100 to +200 °C. These data are applied to the digital telemetry system and samples are obtained every 147, 18.4, and 2.3 seconds for 1, 8, and 64 kb/s data rate.

Automatic Calibrator:

Every 16 sweeps of the sweeping receiver a spectrum of 1 kHz and its harmonics are applied to the antenna for purposes of calibration.

Table 1.2

GROUND COMMANDS AND RECEIVER MODES

Command	Receiver Mode, Receiver Configuration and Data Outputs*
PC 40 <u>on</u>	Power <u>on</u> - - - - -
PC 40 <u>off</u>	Power <u>off</u> - - - - -
IC 16	<u>Mode 1</u> ; Bands 1, 2, and 3 sweeping; Broadband amplitude applied to 30-kHz VCO; Band 2 LO applied to SP TLM
IC 17	<u>Mode 2</u> ; Bands 1, 2, and 3 sweeping; Broadband amplitude applied to 30-kHz VCO; Broadband spectrum applied to SP TLM; Band 2 LO applied to SP TLM
IC 18	<u>Mode 3</u> ; Bands 1, 2, and 3 fixed frequency; Band 3 amplitude applied to 30-kHz VCO; Band 3 phase (53 kc) applied to SP TLM; Band 2 LO applied to SP TLM; first IC 18 after IC 16 or IC 17 sets receiver frequency to high end, next IC 18 resets frequency to low end, subsequent IC 18's step frequency by one step
IC 19	Same mode and data output as IC 18 except following frequency sequence: first IC 19 after IC 16 or IC 17 sets receiver frequency to high end, next IC 19 resets frequency to the seventh step from the low end, subsequent IC 19's step frequency by eight steps.
IC 20	Antenna inflation - - - - -

*In all modes digital data is taken from the outputs of Bands 1, 2, and 3.

2. MECHANICAL DESCRIPTION

2.1 EP-5 ASSEMBLY

The antenna, antenna inflation mechanism, and preamplifier are part of the EP-5 Assembly located at the end of a long boom (see Fig. 1.1). The three-axis search coils and preamplifiers of the UCLA-JPL magnetometer experiment are also located in EP-5. A four-legged fiberglass structure extends from the baseplate of EP-5 to support the antenna and inflation mechanism clear of the search coils. A three-sided cradle on top of the legs projecting away from the spacecraft supports the furled antenna and contains the manifold which supports the antenna after inflation. The inflation mechanism is mounted beneath the antenna support cradle and is arranged for convenient access to the argon gas bottle and squibs. A Mylar-aluminum laminate flap covers the furled antenna and is secured by a nylon cord, which is routed through a guillotine in the inflation mechanism. The flap is attached to the antenna so that it will not fly free during inflation. The nylon cord is composed of three strands of 25-lb-test monofilament nylon fish line. After inflation of the antenna, the argon gas is automatically discharged through an exhaust jet directed radially outward from the center of mass of the spacecraft. A temperature sensor is mounted inside the antenna manifold to monitor the temperature of the furled antenna.

The unfurled antenna has the shape of a torus with overall diameter of 2.9 m and tube diameter of 7.6 cm. The antenna is oriented so that the plane of the loop is in the satellite X-Y plane (horizontally oriented with respect to earth). The wires connecting the antenna to the pre-amplifier are routed around the outside of the EP-5 Assembly to form a backup loop of approximately 0.1 m^2 area.

The preamplifier electronics are contained in an aluminum housing with dimensions $4.7 \times 4.7 \times 7.8$ cm. One multipin connector provides connection between the preamplifier and the main-body unit. The antenna

connection posts protrude from the bottom of the preamplifier and pass through insulators through the EP-5 baseplate to which the preamplifier is mounted. The backup loop is connected to these protruding posts. The posts are accessible for attaching a calibration antenna for prelaunch tests.

2.2 MAIN-BODY ASSEMBLY

The main-body assembly (see Fig. 1.3) is an aluminum structure with overall dimensions of 15.5 x 19.0 x 9.2 cm. The unit is composed of three basic components: a baseplate, six modular containers for receiver electronics, and one modular container for decoupling and interface circuitry. The baseplate provides support for the modules and contains channels between modules for interwiring. This interwiring is soldered directly to the module terminals, eliminating connectors, and is accessible through a removable bottom cover (this cover can be removed only by removing the assembly from the spacecraft). The assembly is secured to the spacecraft (on the +Z door) by nine bolts through the baseplate. Electrical connection is made to the assembly through the multipin connectors located on the decoupling module; one connector is used for normal flight interface, the other connector is used for monitoring critical functions during prelaunch tests.

Each module contains two circuit boards mounted back-to-back and supported in the module by potting with a rigid, light-weight polyurethane foam. Connection is made between the boards as well as to other modules by soldering directly to the circuit boards; therefore, the modules are not easily replaceable but can be removed in case of malfunction by unsoldering.

The baseplate, modules, and bottom cover are all fabricated from thin aluminum sheet stock with welded joints. The components are fastened together with machine screws screwed into captive nuts.

3. ELECTRONIC DESCRIPTION

Refer to Fig. 3.1 for the following discussions.

3.1 ANTENNA AND PREAMPLIFIER

The 2.9-m loop antenna is inflated (after the boom is deployed) by means of the antenna inflation mechanism. The spacecraft Impulse Command 20 closes the relay that applies experiment ordnance power to the squibs. Two squibs, fired simultaneously for reliability, energize the actuator which in turn accomplishes three functions:

- (1) Severs the antenna tie-down cord
- (2) Punctures the argon gas bottle, releasing the gas into the antenna
- (3) After the gas pressure in the gas bottle has decreased to a certain lower level, releases the gas from the system through a directed nozzle.

To prevent undesirable satellite spin, the gas release nozzle is directed radially away from the satellite center of mass.

A temperature monitor is located at the base of the antenna primarily to observe that the antenna temperature is within safe limits (-10 to $+60^{\circ}\text{C}$) at the time of inflation; however, it is used to monitor temperature throughout the life of the satellite. The temperature monitor consists of six forward-biased silicon diodes connected in series. Bias current is provided either from the experiment main-body package or from the experiment ordnance bus; slightly different calibration results depending upon whether one or both of the two sources are on. Variation of the diode junction voltage with temperature is used to determine temperature. This signal is applied to Subcom Word 83 on both digital telemetry equipment groups (EG1 and EG2).

The erected loop antenna is connected to a matching transformer in the preamplifier package by two wires that are routed around the boom package in such a way as to provide a small backup loop with approximately 0.1 m^2 of included area. This backup loop is used to observe the

relatively high signal level present when the boom package is folded against the spacecraft body during pre-launch and launch operations but is intended primarily as a low-sensitivity backup antenna in case the large loop fails to erect.

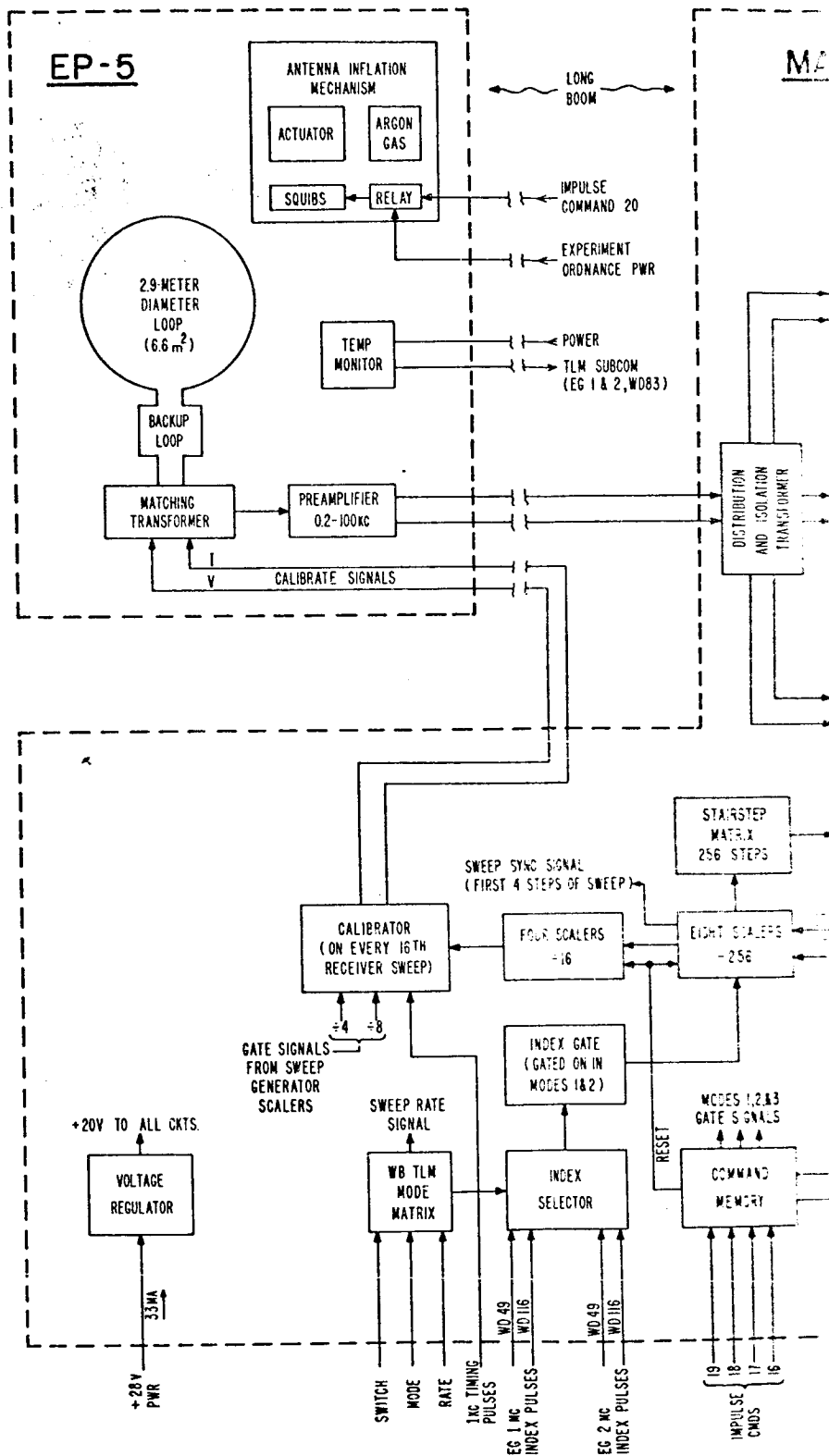
A matching transformer couples the antenna to the preamplifier and transforms the antenna impedance to give maximum sensitivity. Due to the wide variation of antenna reactance with frequency over the frequencies of interest, the optimum impedance is presented to the preamplifier at only one frequency; this was chosen to be 100 kHz. A shunt winding on the matching transformer provides an input for injecting a current calibration into the antenna. A separate transformer in series with one of the antenna leads is used to inject the voltage calibration.

A low-noise broadband preamplifier is used to amplify the signal to a level sufficiently high so that either thermal noise in the following circuitry or interference signals from the satellite are below the minimum signal level from the preamplifier. The preamplifier minimum signal output is determined by the preamplifier thermal noise contribution and the satellite interference received by the antenna. The preamplifier has a noise temperature of approximately 50°K. The preamplifier is a voltage amplifier with flat frequency response from 0.2 to 100 kHz; therefore, the output of the preamplifier increases with increasing frequency because the loop antenna open circuit voltage increases with frequency for a constant excitation field.

3.2 Main-Body Components

3.2.1 General

The main-body receiver package contains the three narrow-band sweeping receivers and the broadband receiver. The electronics necessary to operate these receivers in various modes--using observatory supplied facilities such as timing, indexing, commands, and power, and providing the proper interface circuitry for compatible operation with the spacecraft--are included in this package. Following is a description of the various receiver functions (refer to Fig. 3.1).



MAIN BODY

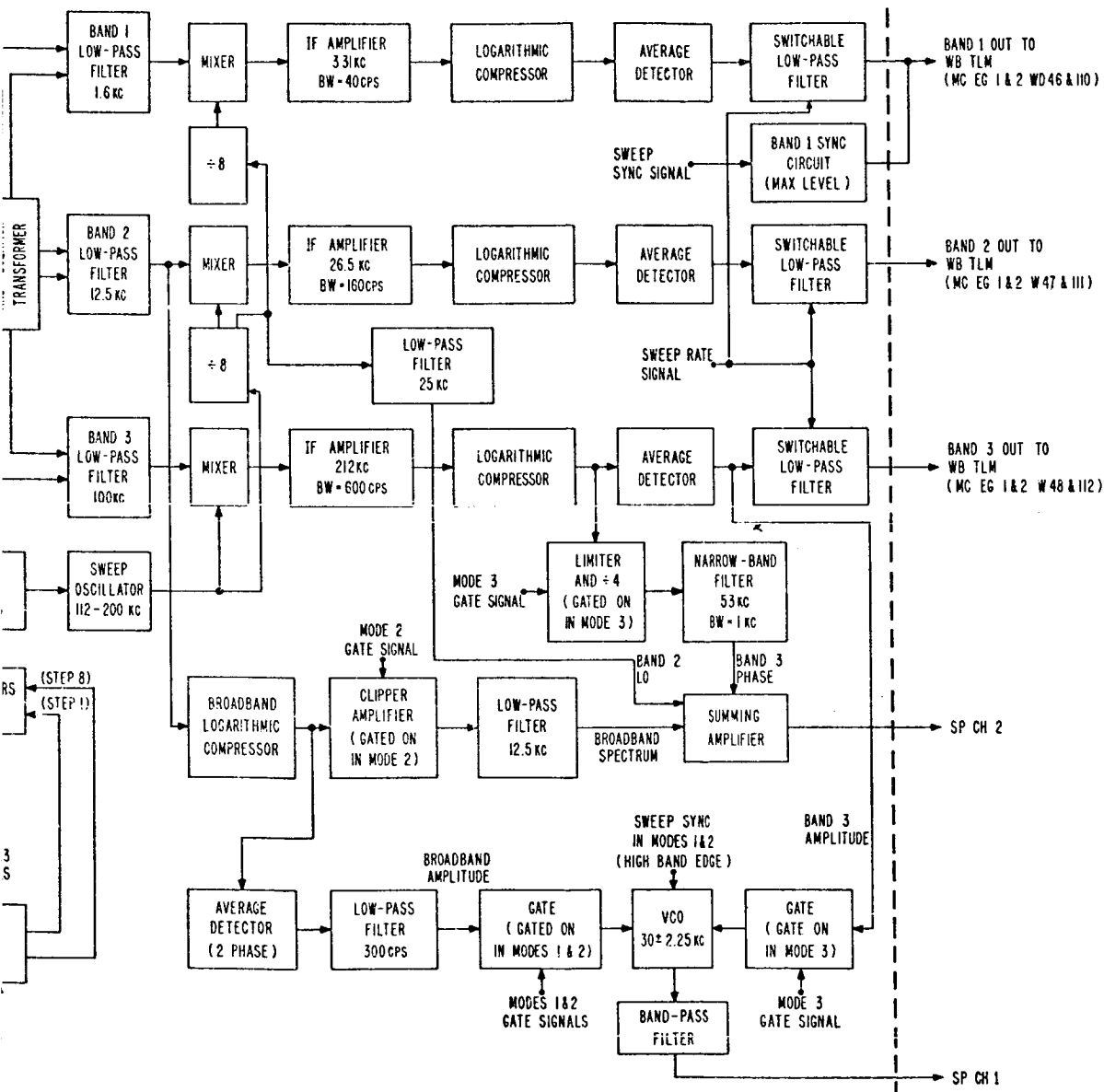


FIG. 3.1 RECEIVER BLOCK DIAGRAM

3.2.2 Narrow-Band Sweeping Receivers

The low-impedance output of the preamplifier is connected to a distribution and isolation transformer which distributes the signals among and provides isolation between the three narrow-band receivers. The output of this transformer is applied to three low-pass filters with upper cutoff frequencies corresponding to the maximum frequency in each band. The Band 2 low-pass filter also serves for the broadband receiver. The pass-band ripple of each filter is less than 1 dB and the stop band exceeds 90 dB. The filter zeros of transmission exist at the IF frequency and in the image band to give additional protection against IF and image band signals.

The mixer for each receiver is a saturating switching transistor operated in inverted configuration (interchange of collector and emitter operation) to minimize local oscillator feedthrough. The local oscillator signal at the output of each mixer is on the order of 50 dB below the IF signal at maximum signal level. The generation of the local oscillator signals is described in Sec. 3.2.3.

The IF amplifiers consist of several LC filter sections with amplifiers between stages for gain and isolation. The IF filter configurations for Bands 1, 2, and 3 are two single-tuned and two double-tuned, two double-tuned, and two double-tuned, respectively. For Bands 1, 2, and 3 the IF frequencies are 3.31, 26.5, and 212 kHz; the 3 dB bandwidths are 40, 160, and 600 Hz; and the 60 dB bandwidths are 450, 1300, and 4500 Hz, respectively.

The IF amplifiers are followed by tuned logarithmic compressors that compress an 80 dB dynamic range of input signal into approximately 20 dB output range. The log compressors are instantaneous, rather than AGC type, and provide response times which are fast compared to the signal changes allowed by the narrow-band IF's.

The log compressors are followed by half-wave average detectors to provide the dc output for the telemetry system. Feedback is used to improve linearity, and the nonlinearity contributed by the detectors is negligible (compared to the small nonlinearity in the log compressors).

The output of the detectors is filtered, or integrated, by means of a single RC filter. The time constant of the filter is automatically switched to one of three values to provide the maximum filtering without loss of data for each receiver sweep rate (determined from the spacecraft telemetry bit rate and configuration). The receiver output (0 to 5V) is sampled twice each main frame of the digital telemetry system which corresponds to 110 samples per second at 64 kb telemetry bit rate and proportionately less at 8 and 1 kb. At the beginning of each receiver sweep a full-scale level is applied to the output of Band 1 for four data words to provide synchronization information for data reduction.

The additional phase and amplitude outputs from Band 3 are described in Sec. 3.2.5.

3.2.3 Local Oscillator Signal Generation and Control

The local oscillator (LO) signals for the three narrow-band sweeping receivers are provided from a single current-controlled multivibrator. Signals for Band 3 are generated directly; signals for Band 2 by dividing by eight; and signals for Band 1 by dividing the Band 2 frequency by eight again. The Band 2 local oscillator is recorded by the Special-Purpose telemetry system and provides a determination of the frequency to which the receivers are tuned. The multivibrator can be set to any one of 256 frequency steps between 112 and 200 kHz; these steps are determined by a staircase matrix. The staircase matrix consists of a set of resistors that provide binary steps in current and are connected to appropriate outputs of the scalers to provide 256 equal steps in current as the scaler sequences through its 256 states. The output frequency of the multivibrator is directly proportional to the control current. The multivibrator, matrix, and scaler outputs are designed to give drifts of local oscillator frequency with temperature and age in the order of 1 percent. The oscillator frequency is linear with steps to within one-half step.

The scalers are low-current flip-flops connected as a binary counter which operate either from index pulses from the spacecraft

digital telemetry system or from pulses generated in the command memory which were initiated by ground command. In the automatic sweep mode, index pulses step the frequency of the oscillator two times each scan of the telemetry main-frame commutator; this corresponds to one frequency step for each output data word from the receivers. Since the IF frequency is equal to the difference between the RF and LO frequency, the LO frequency is made to decrease in frequency each step so that the frequency to which the receiver is tuned increases each step. The receivers reset to the low-frequency end of each band one step after the high-frequency end is reached. The LO signal can be stepped by ground command by either 1 or 8 steps at a time. (See Table 1.2 for a summary of ground command operation.)

3.2.4 Broadband Receiver

The broadband receiver derives its input from the output of the low-pass filter of the Band 2 sweeping receiver, and is therefore sensitive to signals up to 12.5 kHz. The input signals in the frequency range 0.3 to 12.5 kHz are logarithmically compressed to preserve approximately 80 dB of dynamic range. The log compressor is an instantaneous compressor, rather than an AGC type, and has time response determined by the 12.5 kHz bandwidth. The amplitude and spectral distribution of signals are recorded as follows.

In the amplitude channel, a two-phase detector follows the logarithmic amplifier. A two-phase detector is used so that a 300-Hz bandwidth can be maintained at the output for signals down to 300 Hz and also reduces ripple in the output signal. The data output is limited to 300-Hz bandwidth by an RC low-pass filter. The output of the detector is applied, through a gate, to a voltage-controlled oscillator (VCO) that is applied in turn through a filter to the spacecraft analog (Special-Purpose) telemetry system. The VCO is modulated by the input signal to give an output signal frequency of 30 ± 2.25 kHz. The bandpass filter following the VCO attenuates the harmonics of the VCO signal. The broadband amplitude is gated to the VCO only in Modes 1 and 2 (see Table 1.2).

In the spectral or phase channel the output of the log compressor is fed to a clipper amplifier, which removes the amplitude information from the signal but retains the spectral distribution of the original signals with the addition of odd harmonics. The clipper amplifier is gated on in Mode 2 (see Sec. 1.3). The clipper amplifier is followed by a filter to suppress the harmonics above 12.5 kHz. The output of the filter is applied to a summing amplifier. The summing amplifier combines the broadband spectrum data with the Band 2 local oscillator signal and applies these signals to the spacecraft analog (Special-Purpose) telemetry system. (In Mode 3 the summing amplifier is used for the Band 3 IF signal and the Band 2 local oscillator signal.)

3.2.5 Band 3 Phase and Amplitude

In addition to the digital amplitude data taken on Band 3, the amplitude and phase of the Band 3 signals are transmitted by the analog telemetry in Mode 3. The amplitude data, with approximately 500-Hz bandwidth, is applied to the VCO through a gate circuit that is on in Mode 3. These amplitude data are the same as those applied to the digital telemetry system, but have a substantially higher information rate.

To obtain the phase data, the IF signal is divided by four to reduce the frequency to a value suitable for recording, passed through a narrow-band filter to remove harmonics, and then applied to a summing amplifier that provides the output to the analog (Special-Purpose) telemetry system. The phase ambiguity introduced by the LO is removed on the ground by re-adding the LO signal, which is also recorded, to the IF signal. Relative phase of the incoming RF signal in Band 3 can then be determined.

3.2.6 Voltage Controlled Oscillator (VCO)

The VCO is used to convert the amplitude data from Band 3 and the broadband receiver to a frequency-modulated subcarrier to apply to the analog telemetry system. The analog telemetry transmitter is phase modulated so that a FM/PM system results. The VCO is an emitter coupled multivibrator that varies in frequency from 27.75 to 32.25 kHz for a full

range of input signals. The output is first filtered to remove harmonics and then applied to the telemetry system.

3.2.7 Calibrator

The automatic calibrator provides signals that are applied to the antenna system to calibrate the entire receiver. The calibrator is actuated automatically once every 16 sweeps of the narrow-band sweeping receivers. The gate signal is generated by a divide-by-sixteen circuit that receives a pulse from the last scaler in the LO sweep generator once every sweep of the LO.

The calibrator circuit generates a sawtooth signal at a 1-kHz rate, determined by a spacecraft timing signal, that results in spectrum of signals at all harmonics of 1-kHz over the entire frequency range of the receiver. The spectrum amplitude decreases linearly with frequency. Two outputs are generated by the calibrator; one is used for current injection at the antenna, the other is used for voltage injection at the antenna. The transfer function of both calibrate injection circuits increases linearly with frequency; therefore, the spectrum of the calibrate signal at the output of the preamplifier is constant with frequency.

In addition to the gate signal that energizes the calibrator every sixteenth sweep, gate signals representing every four and eight steps of the sweep scaler are used to sequence the calibrator through outputs of high-level voltage, high-level current, low-level voltage, and low-level current, each condition lasting for four steps of the sweep receivers.

3.2.8 Command Operation and Receiver Logic

The ground commands that are transmitted to the spacecraft appear as either a momentary relay contact closure (known as an Impulse Command) or a continuous supply of spacecraft power through a relay closure (known as a Power Command).

The use of Impulse Command (IC) 20 for erection of the loop antenna is described in Sec. 3.1. IC 16, 17, 18, and 19 are applied to a four-state command memory, which converts the momentary signal to a continuous

state in the command memory; IC 16 energizes Mode 1, IC 17 energizes Mode 2, IC 18 and 19 energize Mode 3. Only three states of the command memory are used. A reset signal is produced whenever the command memory is switched between either Mode 1 or 2 to Mode 3; this occurs the first time IC 18 or 19 is sent after the memory has been in Mode 1 or 2. The reset signal sets the sweep receiver tuning to the high end of the band and resets the scaler that energizes the calibrator to the zero state (calibrator OFF). Subsequent transmissions of IC 18 and 19 will step the sweep oscillator by one and eight steps, respectively.

The spacecraft has two digital telemetry equipment groups (E.G. 1 and 2) to sample data and either record on magnetic tape or transmit in real time to the ground receiver. The output from either E.G. may be transmitted in real time, in which case the other output is recorded or, in the case where no real-time transmissions are possible, the output from either E.G. may be recorded. The recordings are limited to 1 kb data rate; however, the real-time transmission rate may be 1, 8, or 64 kb. The Mode, Rate, and Switch signals from the spacecraft represent the status of the E.G.'s. The logic circuitry in the receiver uses these signals to determine the data integration time constant (TC) for the three sweeping receiver outputs corresponding to the E.G. being used and to select the index pulses from the desired E.G. The desired E.G. is the one transmitting real-time data or, in case no real-time data is being transmitted, the E.G. being recorded. Table 3.1 presents in detail the various telemetry, data integration time constants (1, 8, or 64 kb), and index conditions.

3.2.9 Voltage Regulator

The series-type voltage regulator provides constant voltage output (20 V) for variable input voltage (nominally 23.5 to 33.5 V, but with surges to 50 V for 10-ms duration). In normal operation, the regulator is approximately a constant current load (in this case 33 mA) to the spacecraft power supply. Except for the inherent power loss of this type of regulator (series), the circuit is designed for maximum efficiency. In terms of input current, 1.5 mA is used in the regulator and 31.5 mA is supplied to the load.

Table 3.1
WIDEBAND TELEMETRY OPERATIONAL SIGNALS

Function	State	Voltage	
Switch: {	1	0-2.0	E.G. 1 transmitting, or if no real-time, 1 recording
	2	7-33.5	E.G. 2 transmitting, or if no real-time, 2 recording
Mode: {	3	3.9-9.0	E.G. 1 connected to transmitter, E.G. 2 connected to recorder
	4	0-0.6	E.G. 2 connected to transmitter, E.G. 1 connected to recorder
Rate: {	5	3.14-3.46	For 1 kb real-time transmitter setting (voltage always present)
	6	4.85-5.35	For 8 kb real-time transmitter setting (voltage always present)
	7	7.13-7.87	For 64 kb real-time transmitter setting (voltage always present)

Combinations:

Switch	Mode	Rate	Conditions	(TC)	E.G. Index
1 {	3 {	5	1 real-time 1 kb, 2 record	1	1
		6	1 real-time 8 kb, 2 record	8	1
		7	1 real-time 64 kb, 2 record	64	1
	4 {	5	1 recording, real-time off	1	1
		6	1 recording, real-time off	1	1
		7	1 recording, real-time off	1	1
2 {	3 {	5	2 recording, real-time off	1	2
		6	2 recording, real-time off	1	2
		7	2 recording, real-time off	1	2
	4 {	5	2 real-time 1 kb, 1 record	1	2
		6	2 real-time 8 kb, 1 record	8	2
		7	2 real-time 64 kb, 1 record	64	2

High-frequency LC decoupling is provided on both input leads to reduce interference and to limit peak current during the initial portion of the turn-on transient. A current limiter is incorporated to limit the input turn-on transient current or receiver failure current to less than 300 mA. Diode decoupling is included in the input power lines to prevent damage during input power turnoff or short-circuit failure.

4. DATA OUTPUTS

4.1 WIDEBAND TELEMETRY

The outputs of the three narrow-band sweeping receivers are sampled sequentially twice per main-commutator frame of the digital telemetry system. At a telemetry bit rate of 64 kb, each data word is sampled 111 times per second. The data words assigned to this experiment are 36 and 110, 47 and 111, and 48 and 112; corresponding to the outputs of Bands 1, 2, and 3, respectively. Each output has a range of 0 to 5 V, which is proportional to the log-compressed amplitude of the received signal. In Modes 1 and 2, following each sampling of the output of Band 3, the experiment receives an index pulse (during words 49 and 116), which advances the center frequencies of each receiver one step.

In addition to the six data words in the main commutator frame, the experiment uses data word 83 on the experiment subcommutator to relay information on the temperature of the antenna manifold in EP-5. The data word is sampled once each 2.3 seconds when the telemetry data rate is 64 kb. Power for the temperature monitor is provided whenever either the experiment or the experiment ordnance bus is energized.

4.2 SPECIAL-PURPOSE TELEMETRY

The special-purpose telemetry outputs from this experiment occupy two of the five channels available on the spacecraft (Channels 1 and 2). Channel 1 contains a 30-kHz VCO modulated by the amplitude of the broad-band receiver in Modes 1 and 2, and by the amplitude of the signal received by the Band 3 narrow-band receiver in Mode 3. The VCO center frequency is 30 kHz with ± 7.5 percent deviation corresponding to IRIG Channel 15. The output level is 5 V p-p corresponding to maximum channel level.

Channel 2 is a combination of signals. The local oscillator from Band 2 (14-25 kHz) is always present in this channel at a level of

approximately 1.25 V p-p. In Mode 2, the frequency spectrum of signals received by the broadband receiver (0.3 to 12.5 kHz) are added to the channel at 3.75 V p-p amplitude. In Mode 3, the divided IF of the Band 3 receiver, representing the phase of the received signal, is added to the channel at 3.75 V p-p amplitude. These phase signals occur at a frequency of 53 ± 0.5 kHz which is within the range of IRIG Channel 17.

5. PRE-FLIGHT CALIBRATIONS

The calibration curves for each receiver are contained in this section (Figs. 5.2 to 5.7). All responses were taken with the aid of a dummy antenna which is an accurate antenna equivalent. The antenna was considered fully inflated for the purposes of computing receiver sensitivities (expressed in decibels with respect to one gamma of magnetic flux density). Calibrations of the narrow-band receivers were made at frequencies near the upper edge of each band (1.60, 12.7, and 90 kc). To adjust these calibrations for any other frequency within the band of the receiver, they must be adjusted according to the graph of the pre-amplifier frequency response (see Fig. 5.1).

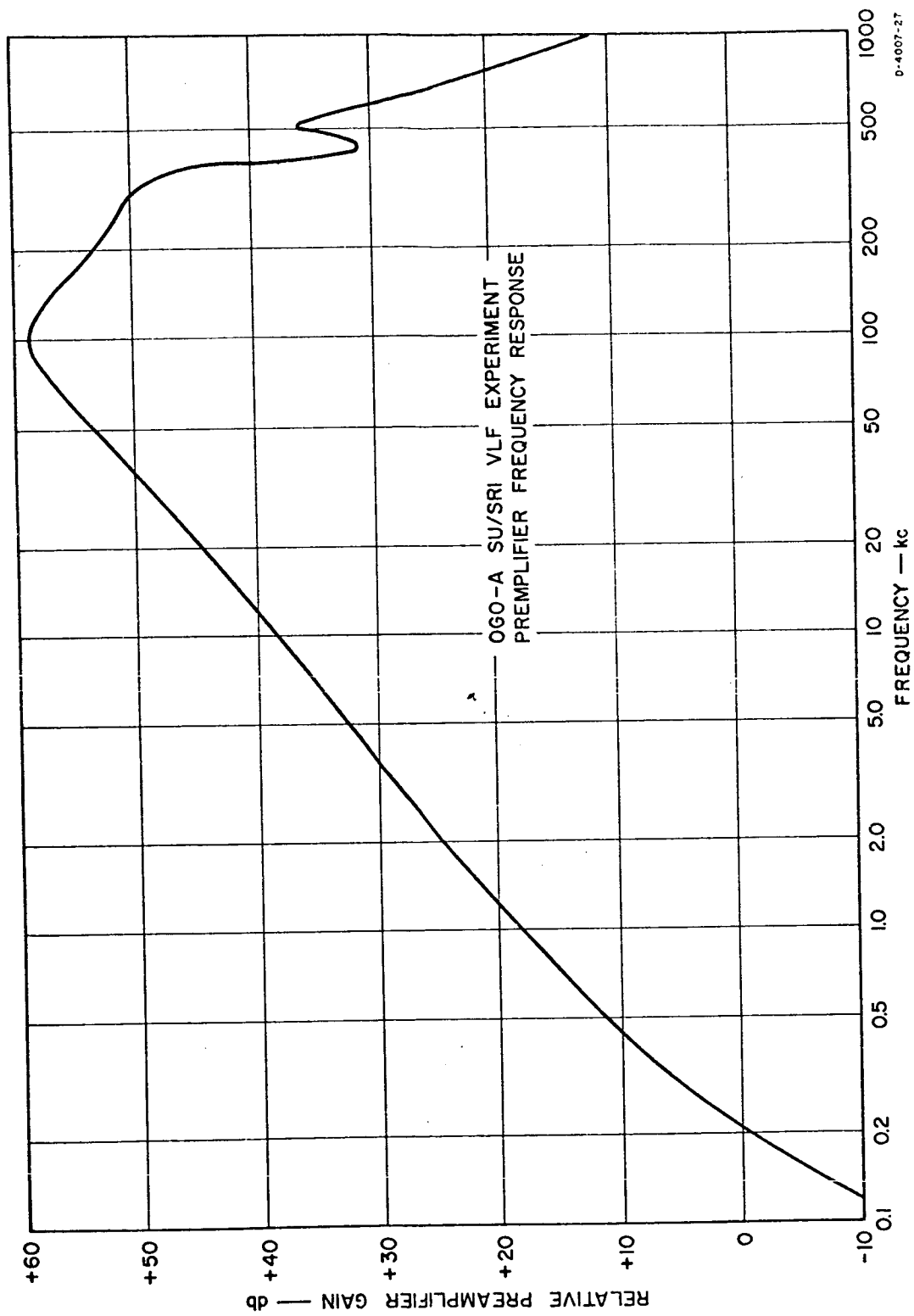


FIG. 5.1 FREQUENCY RESPONSE OF PREAMPLIFIER

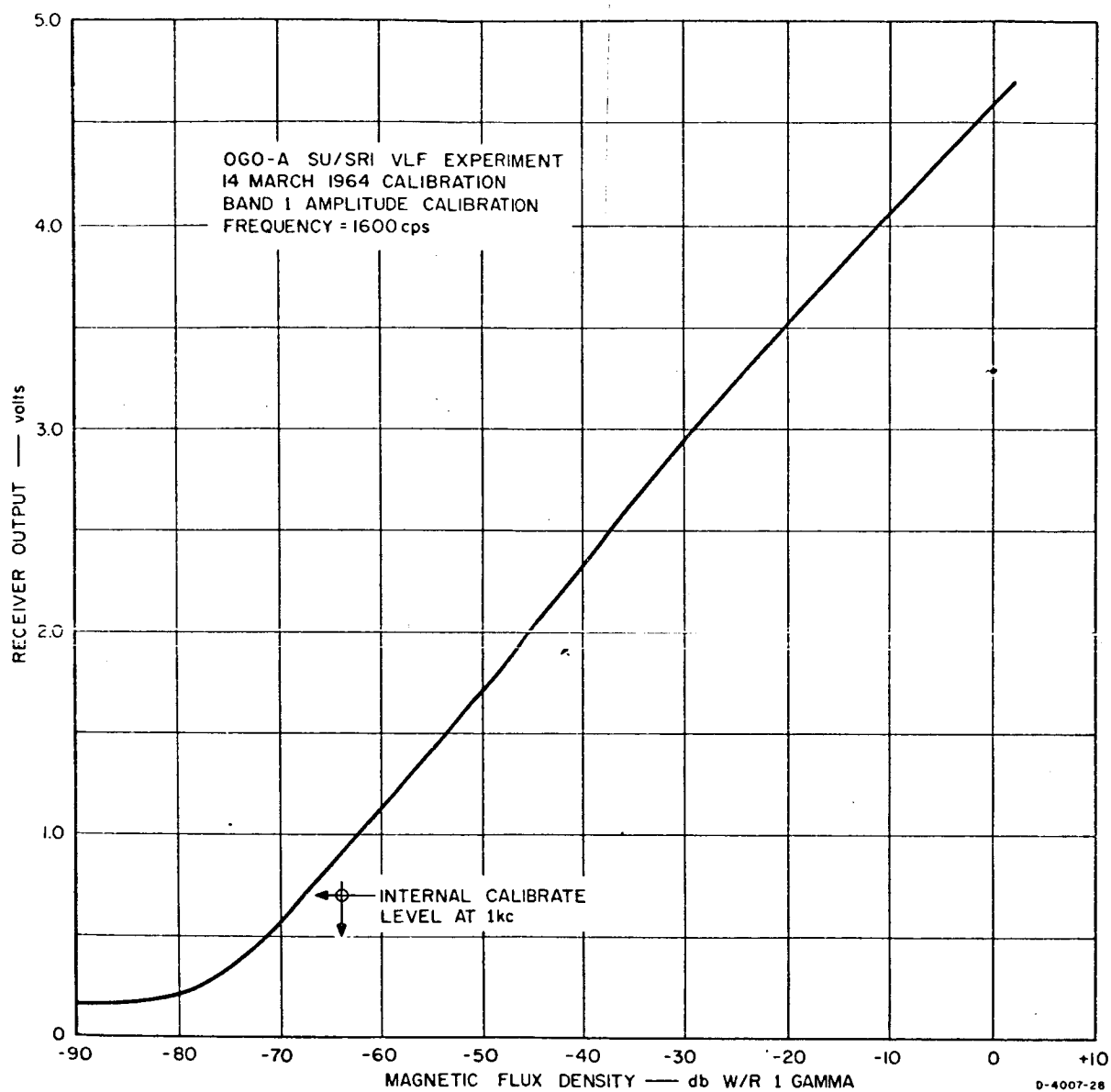


FIG. 5.2 CALIBRATION OF BAND 1

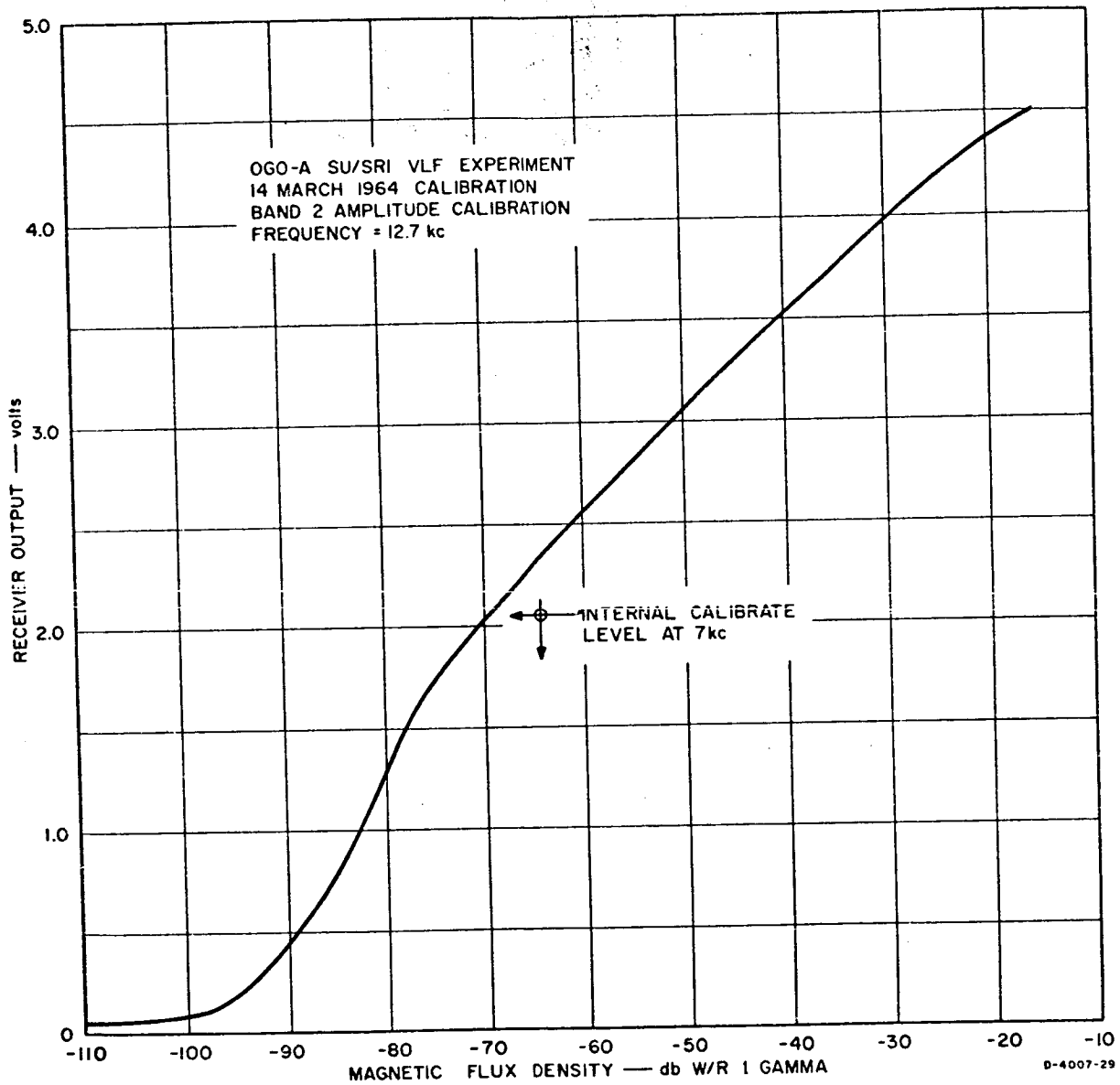


FIG. 5.3 CALIBRATION OF BAND 2

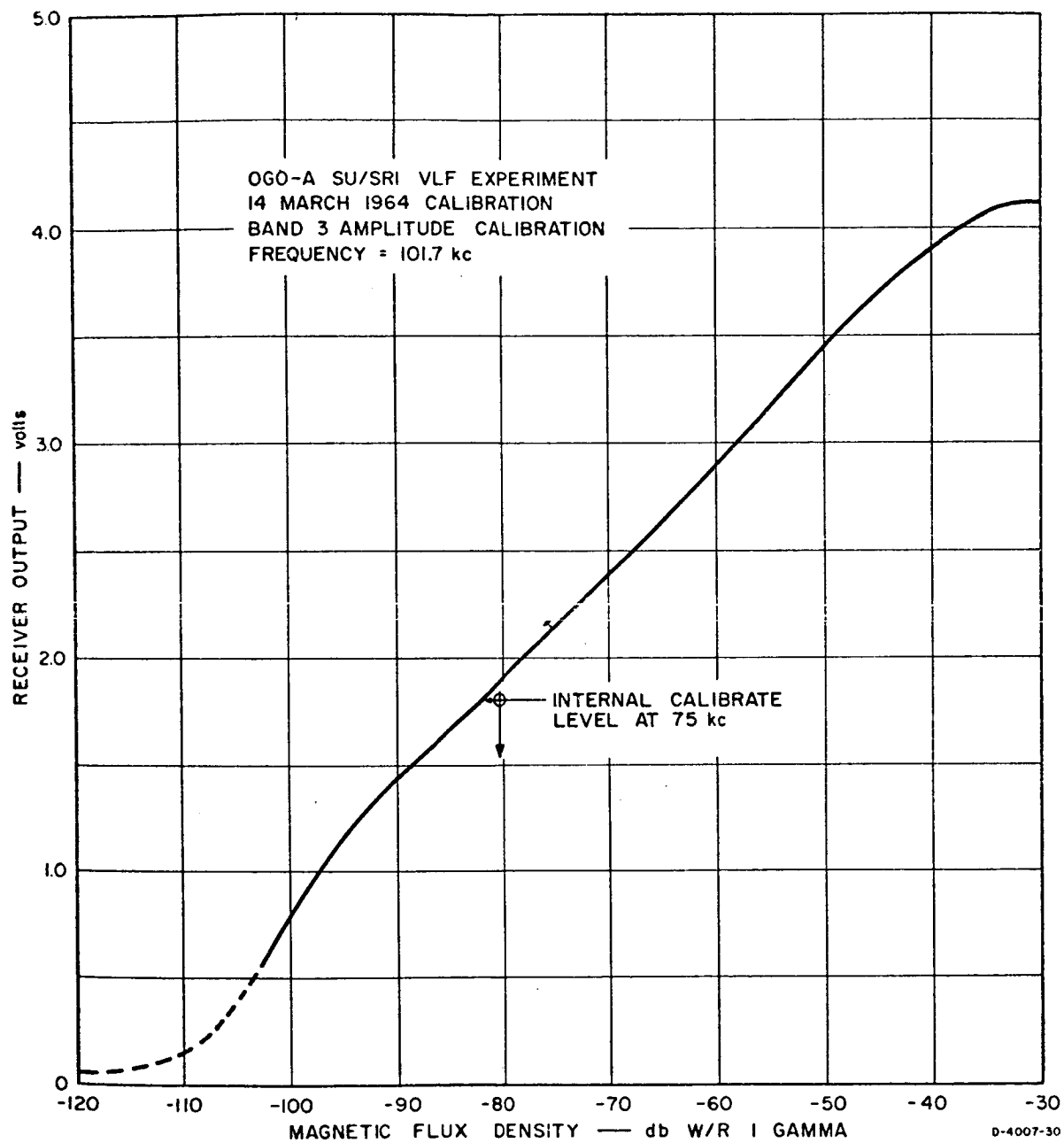


FIG. 5.4 CALIBRATION OF BAND 3

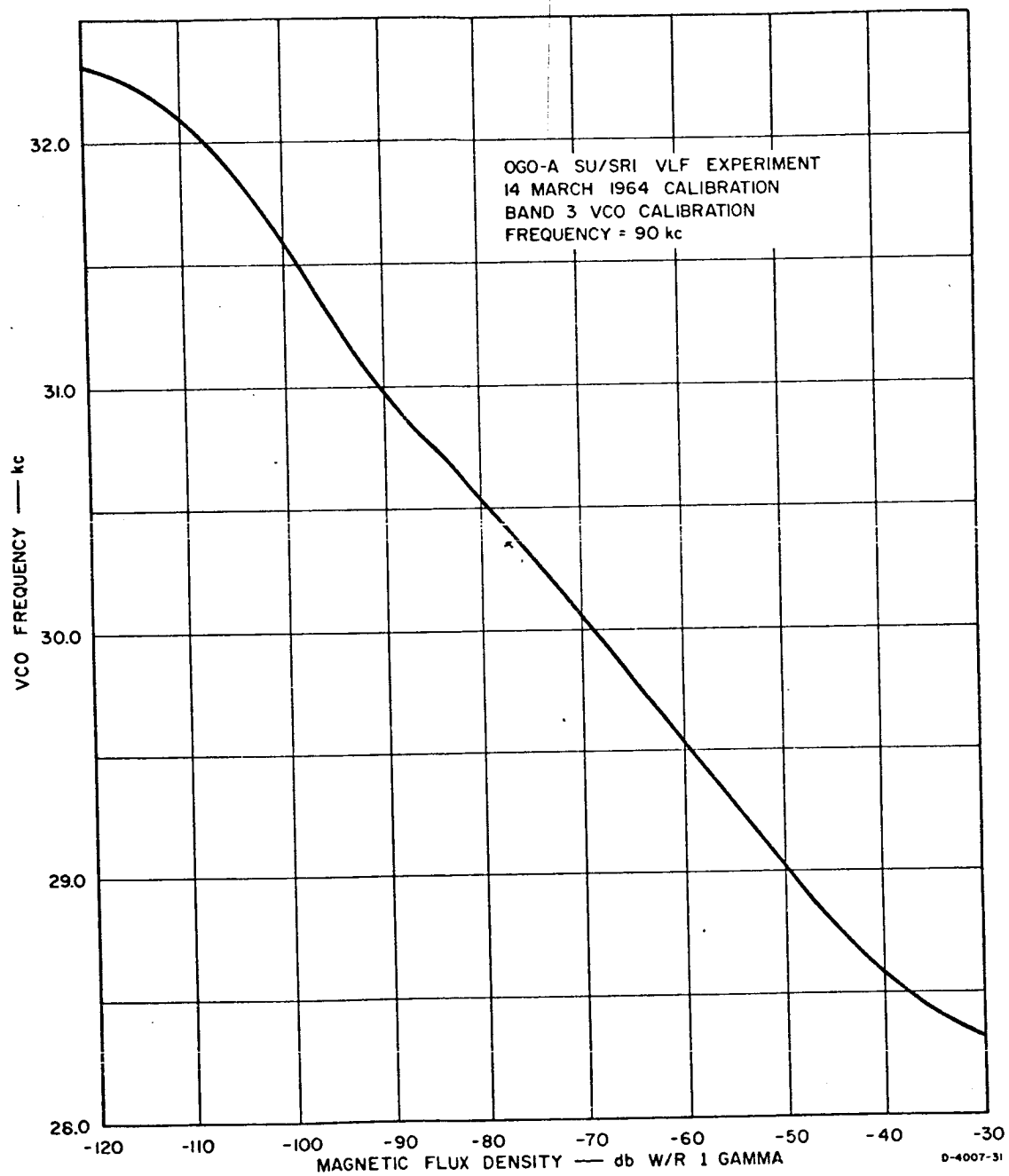


FIG. 5.5 CALIBRATION OF BAND 3 VCO

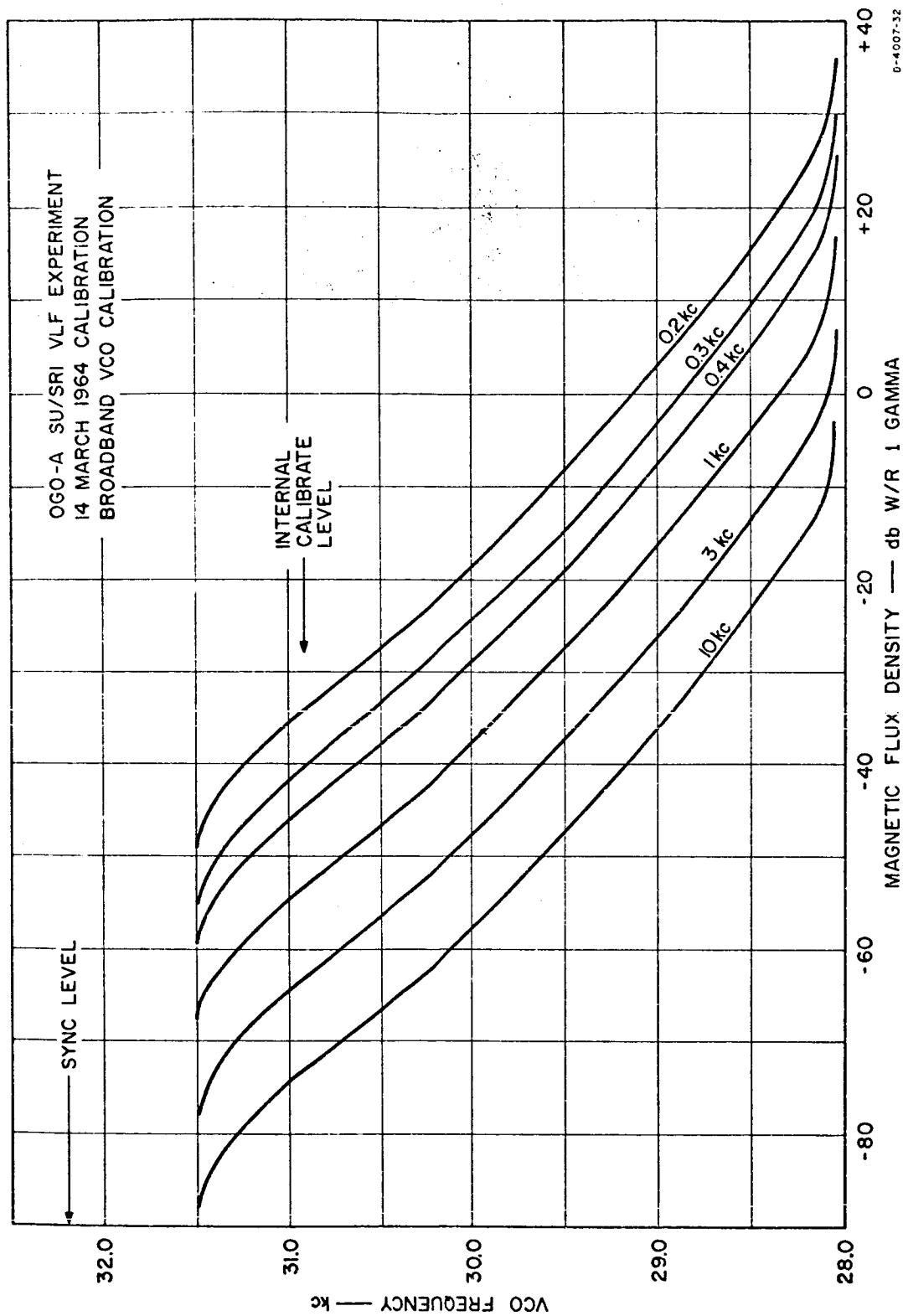


FIG. 5.6 CALIBRATION OF BROADBAND VCO

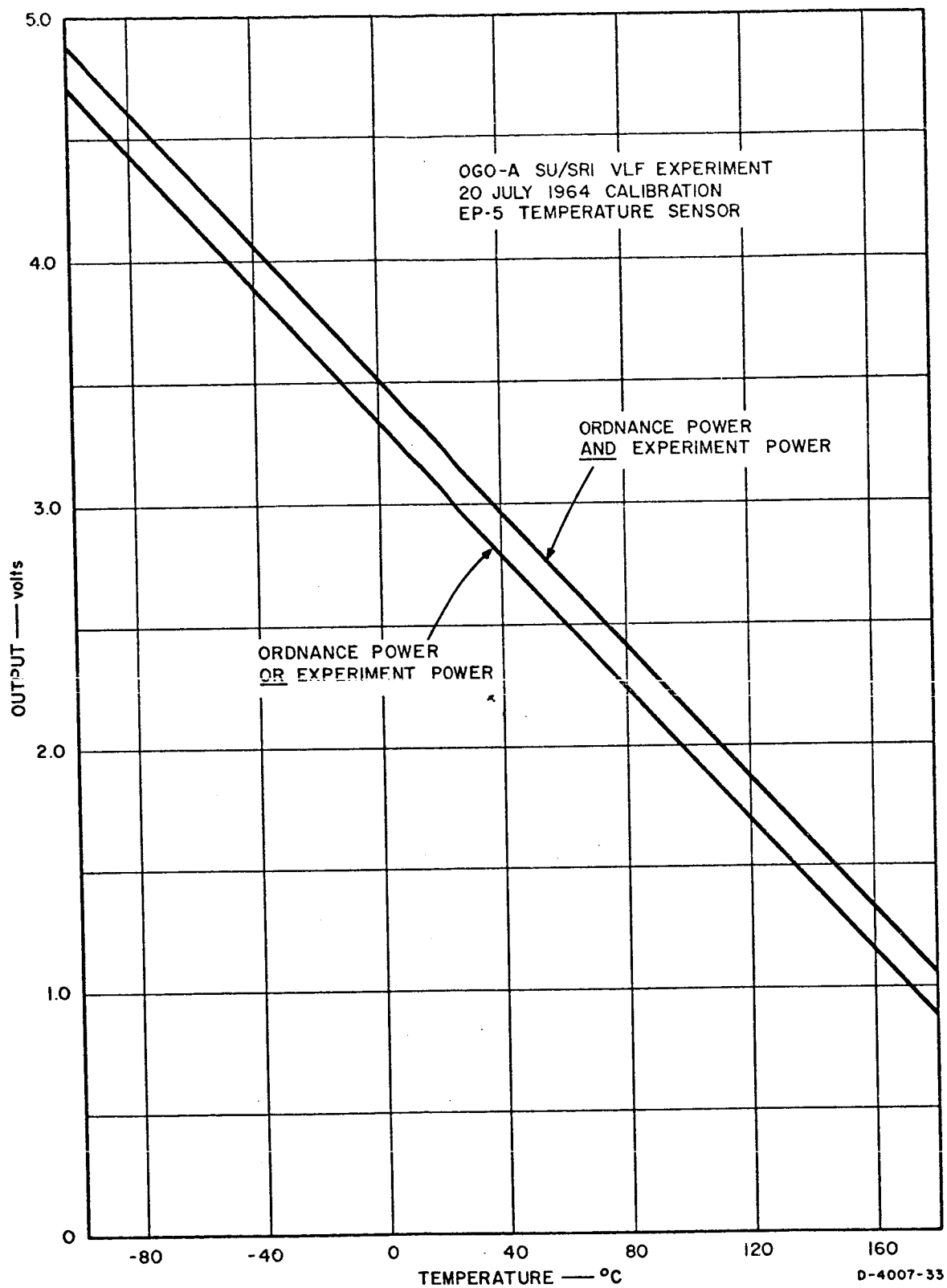
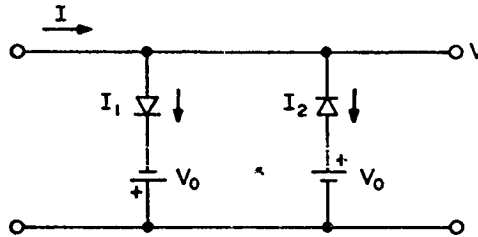


FIG. 5.7 CALIBRATION OF EP-5 TEMPERATURE SENSOR

6. DETAILED DESCRIPTION OF LOG COMPRESSOR

The merits of the log compressor developed for this receiver are its simplicity, wide dynamic range, low power requirement, and temperature stability. It is also an instantaneous compressor that can be used for broadband applications such as the broadband receiver. It has a dynamic range up to 90 dB, is temperature compensated, uses approximately 25 mW of power, and has less than 20 small components. The compressor is based upon the following analysis.

Consider the circuit with diode bias (V_0) and signal current (I) applied as shown.



Then

$$I_1 = I_x \left[\left(e^{q(V+V_0)/kt} - 1 \right) \right], \quad -I_2 = I_s \left[\left(e^{q(V_0-V)/kt} - 1 \right) \right],$$

where I_s is the diode saturation current (assumed to be the same for both diodes). High-quality silicon diodes are assumed so that leakage current may be ignored. The following relations are then obtained

$$\begin{aligned}
I &= I_1 + I_2 = I_s \left[e^{\frac{q(V+V_o)/kt}{}} - e^{\frac{q(V_o-V)/kt}{}} \right] \\
&= I_s e^{\frac{qV_o/kt}{}} \left[e^{qV/kt} - e^{-qV/kt} \right] \\
&= 2I_s e^{\frac{qV_o/kt}{}} \sinh \left(\frac{qV}{kt} \right)
\end{aligned}$$

Solving for V ,

$$V = \frac{kt}{q} \sinh^{-1} \left[\frac{I}{2I_s e^{\frac{qV_o/kt}{}}} \right]$$

If $I = A \sin \omega t$,

then

$$V = \frac{kt}{q} \sinh^{-1} \left[\frac{A \sin \omega t}{2I_s e^{\frac{qV_o/kt}{}}} \right]$$

and the average value of V for full-wave average detection is given by

$$\bar{V} = \frac{kt}{\pi q} \int_0^\pi \sinh^{-1} \left[\frac{A \sin \omega t}{2I_s e^{\frac{qV_o/kt}{}}} \right] d(\omega t)$$

No closed-form solution exists for the above integral, however it can be readily integrated numerically (by computer or graphically). The functions V_p (for $I = A$) and \bar{V} are plotted in Fig. 6.1. The peak voltage V_p is linear to a lower value of input than the average voltage \bar{V} ; however, average detection has greater immunity to noise, particularly impulsive noise. An average detector was used in this instrument.

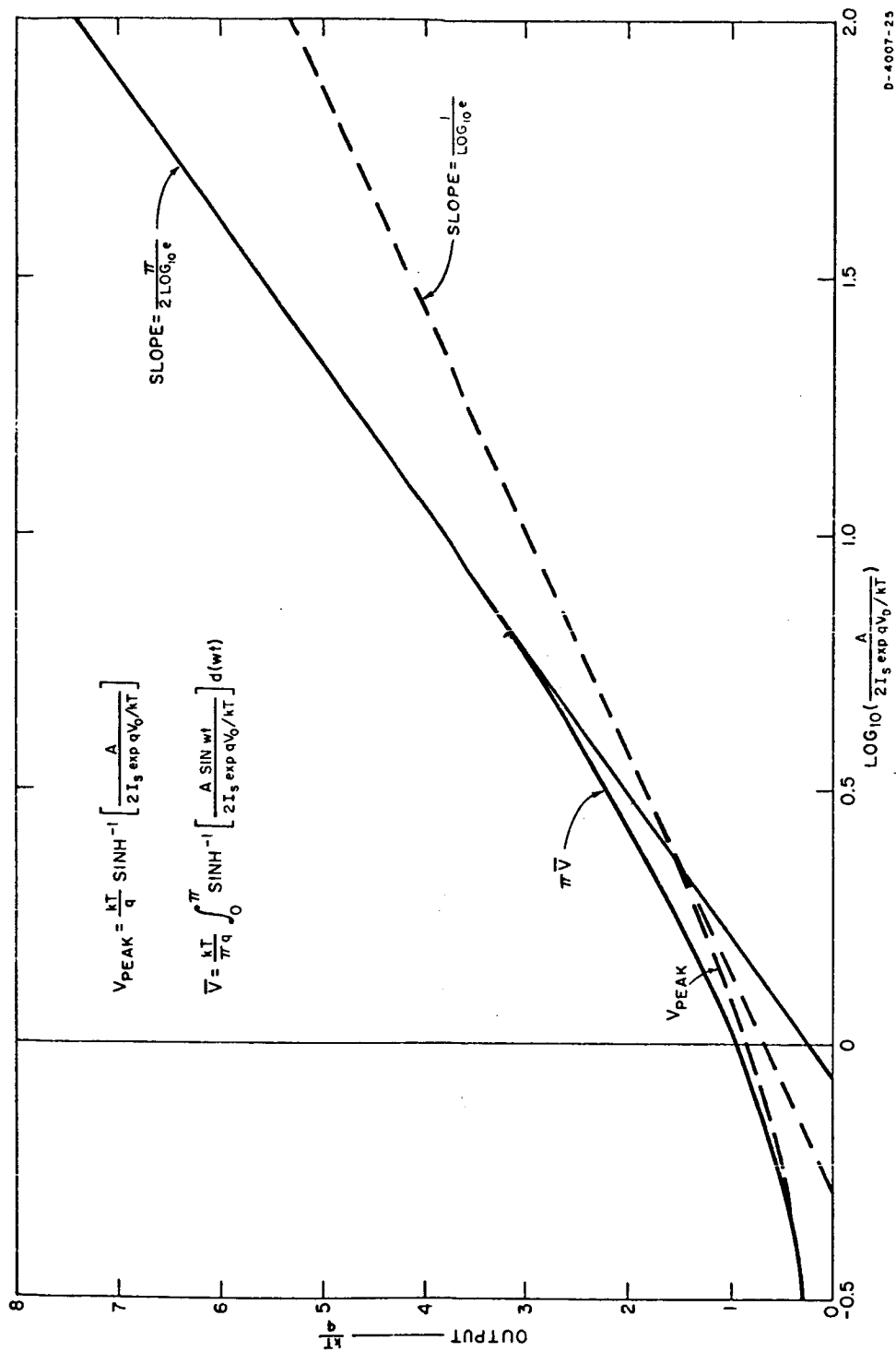


FIG. 6.1 CHARACTERISTICS OF LOG COMPRESSOR

Two temperature variations are significant: One is a linear variation of V or \bar{V} in the term kt/q ; the other is in the term $I_S e^{qV_O/kt}$. The linear variation can be compensated by linear temperature compensation of the detector circuit (see R161 of Band 1 receiver, for example). The variation of the term $I_S e^{qV_O/kt}$ with temperature is compensated by an inverse variation of V_O with temperature. This variation in V_O is approximately equal to the variation needed to maintain a constant diode current with temperature, on the order of -2 to -2.5 mV/ $^{\circ}$ C, depending on the current level.

In the actual circuit developed, a transistor is substituted for one of the diodes and the emitter-to-base junction is utilized in the compressor. This is done so that the temperature-compensated bias may be applied to the base of the transistor, utilizing the current gain of the transistor and thereby reducing the current requirements of the bias circuitry. (See Q115 and CR109 and associated circuitry of Band 1, for example.)

The analysis given above and the curves shown in Fig. 6.1 assume that the signal is applied from a current source. In practice, the admittance of the current driver output and the input to the following amplifier must be considered. The linearity at low levels can be improved if the admittance is chosen or the diode bias is adjusted so that the magnitude of admittance shunted across the compressor is approximately equal to $(2qI_S e^{qV_O/kt})/kt$, i.e., the conductance of the compressor when the peak input current is $2I_S e^{qV_O/kt}$. For wide dynamic range but low peak current, the loading on the compressor must be minimized. For narrow-band compressors, this is accomplished by obtaining the current drive from the collector of a common-base transistor amplifier that has its collector dc current supplied through a high-quality coil. This coil is also used to tune out compressor shunt capacitance. For broadband compressors, a balanced transistor drive amplifier is required and the dynamic range at high frequencies is limited by the shunt

capacitance. The maximum drive level in this case was limited to approximately 1 mA peak current to conserve power; however, drive levels to 100 mA or greater can be used and the logarithmic linearity still maintained. Diode series resistance allows the output to become linear (instead of logarithmic) with respect to input for large drive levels.

7. THERMAL DESIGN CONSIDERATIONS

7.1 EP-5 ASSEMBLY

The design operating temperature range of the antenna and antenna-inflation mechanism is -100 to $+100^{\circ}\text{C}$, except at the beginning of inflation for which it is 0 to $+65^{\circ}\text{C}$. The temperature of the furled antenna is maintained within the limits by a combination of Mylar-aluminum thermal insulation and the EP-5 baseplate heater controlled by ground command. The heater is used to obtain proper inflation temperature. The unfurled antenna is maintained between -100 to $+100^{\circ}\text{C}$ by the proper ratio of exposed aluminum and Mylar on the surface of the antenna.

The design temperature range of the preamplifier is -10 to $+50^{\circ}\text{C}$, although operation and storage over the range of -65 to $+85^{\circ}\text{C}$ is allowable. The preamplifier is maintained within these ranges by a combination of the Mylar-aluminum thermal insulation surrounding EP-5 and the EP-5 baseplate heater. The maximum power dissipated within the preamplifier is 150 mW and the heat can be considered to be uniformly conducted to the aluminum case. The preamplifier is maintained at thermal equilibrium with the EP-5 baseplate by conduction through the mating surfaces.

7.2 MAIN-BODY ASSEMBLY

The design temperature range of the main-body assembly is $+5$ to $+35^{\circ}\text{C}$ but with tested operation over the range from -5 to $+45^{\circ}\text{C}$. Allowable storage temperature range is -65 to 85°C . The maximum power dissipation within the assembly is 1 W . Approximately 600 mW of this power is dissipated uniformly throughout the experiment and is constant; the remaining dissipation is in the series power regulator and varies from approximately 100 to 400 mW depending upon input voltage from the spacecraft. The majority of the power dissipated in the series regulator is conducted to the mounting base of the assembly by use of an

electrically insulating heat sink. The large area of the mounting surface (295 cm^2) and the relatively low power dissipation in the assembly does not allow a significant temperature difference to exist between the assembly and the spacecraft door panel.

8. GROUND SUPPORT EQUIPMENT (GSE)

8.1 BENCH TEST AND CHECKOUT MONITOR

8.1.1 Introduction

The bench Test and Checkout Monitor Ground Support Equipment consolidates, in one compact package, the circuitry necessary to generate simulated spacecraft signals and ground commands for the experiment package and to monitor experiment performance. The set consists of a spacecraft simulator, a checkout monitor, a preamplifier simulator, and a main-body simulator.

The unit is constructed on a standard 19-inch rack panel (Fig. 8.1) and is mounted in an equipment case to provide mechanical protection but insulated from the case to provide electrical isolation from the surrounding environment. The circuitry is located in four chassis boxes suspended from the front panel. These boxes, when properly covered, provide effective shielding for a minimum of interference between the various functions of the unit.

8.1.2 Spacecraft Simulator (Figs. 8.2 and 8.3)

8.1.2.1 Power Supply

The power supply provides a well-regulated voltage, continuously adjustable from 0 to +37 Vdc, to power the experiment. In addition, regulated ± 20 Vdc is supplied to the circuitry in the GSE. A dual half-wave rectifier with capacitive filtering is used to provide the ± 45 Vdc inputs to the regulators. The rectifier is fuse protected and transformer decoupled from the ac line.

The series regulator supplying power to the experiment is an emitter follower driven by a current amplifier. The reference voltage is obtained from a potentiometer connected across a 39-V Zener diode. The current supplied to the experiment is limited to 50 mA by base driven cutoff. The current to the experiment is sensed by the voltage

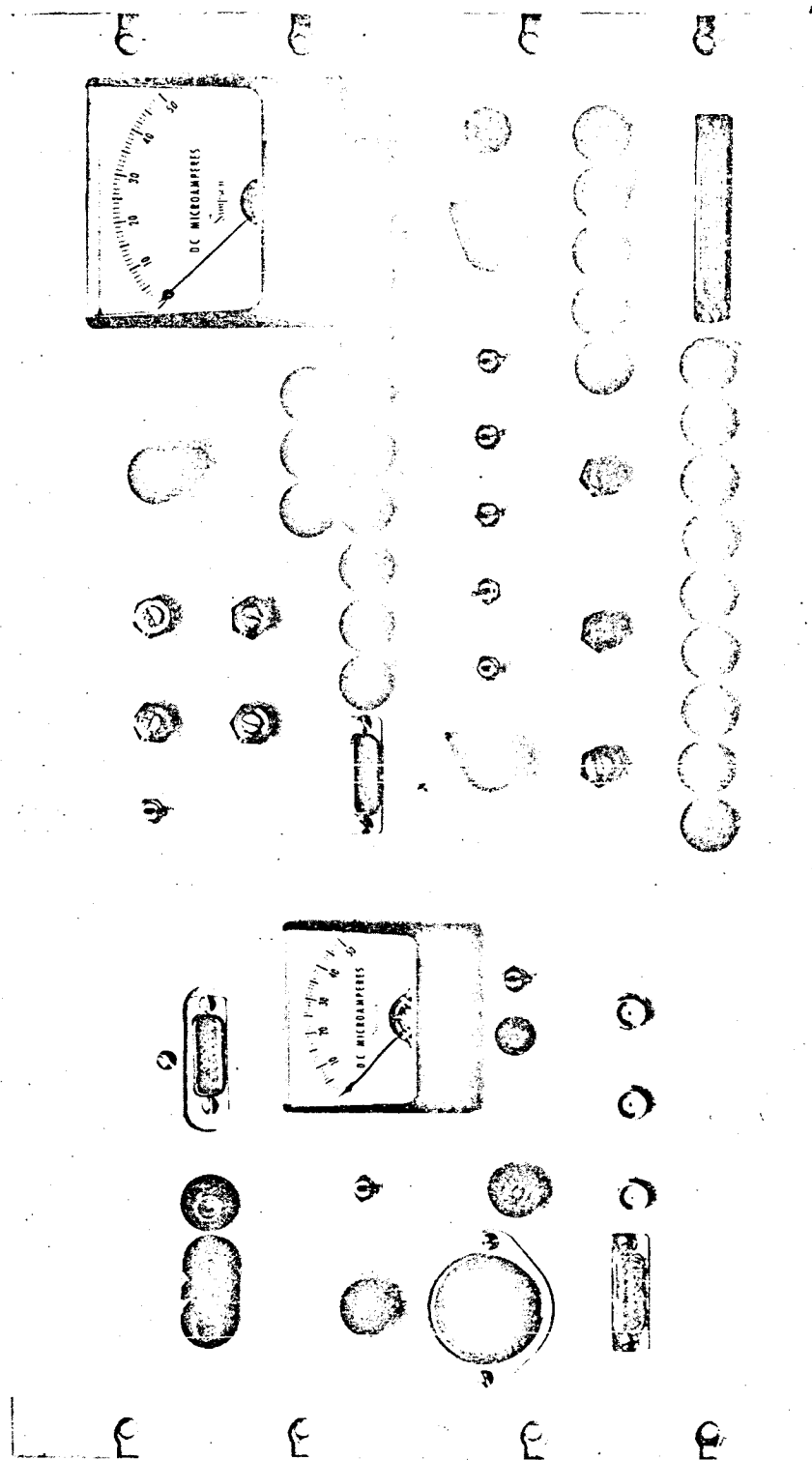
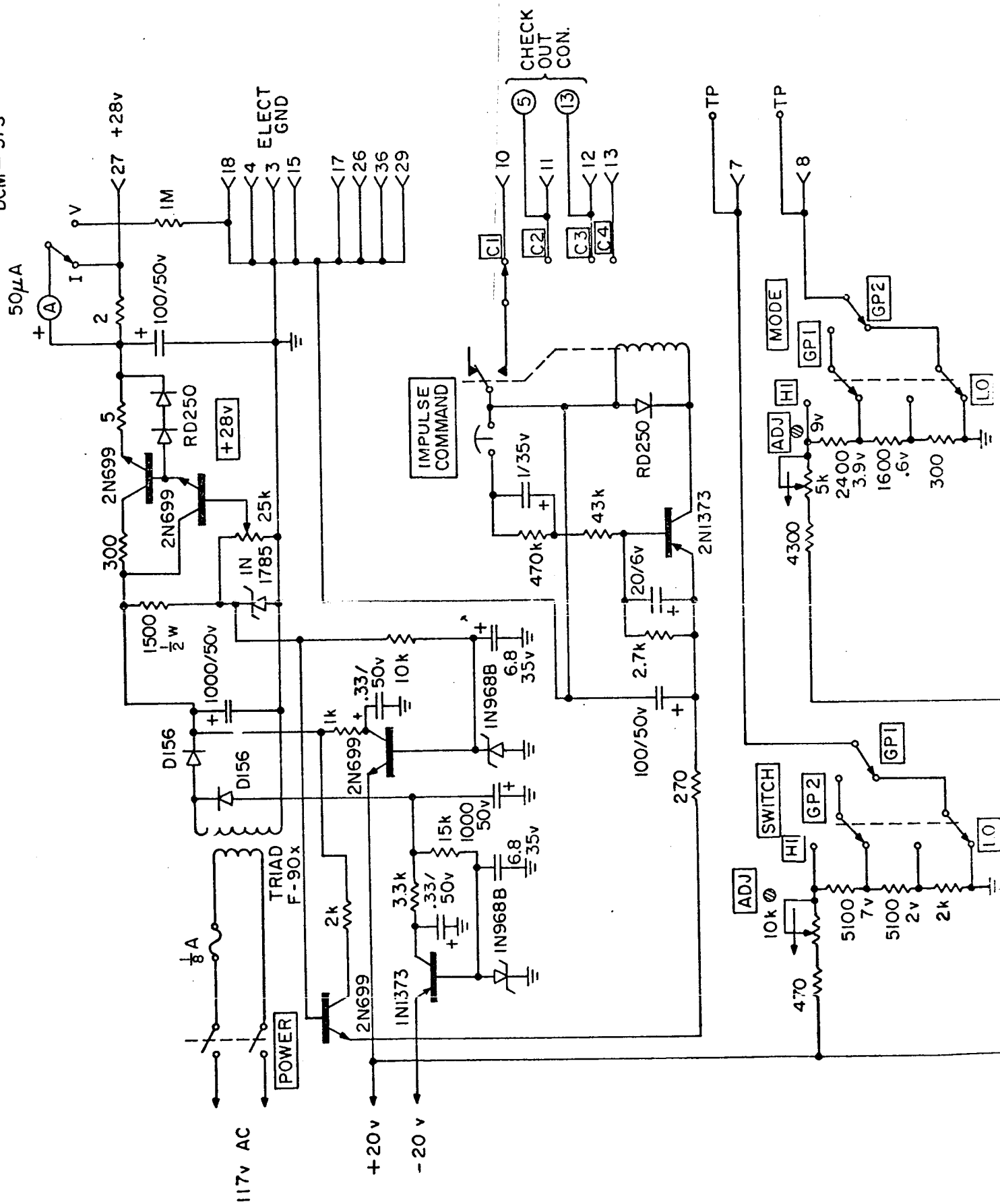
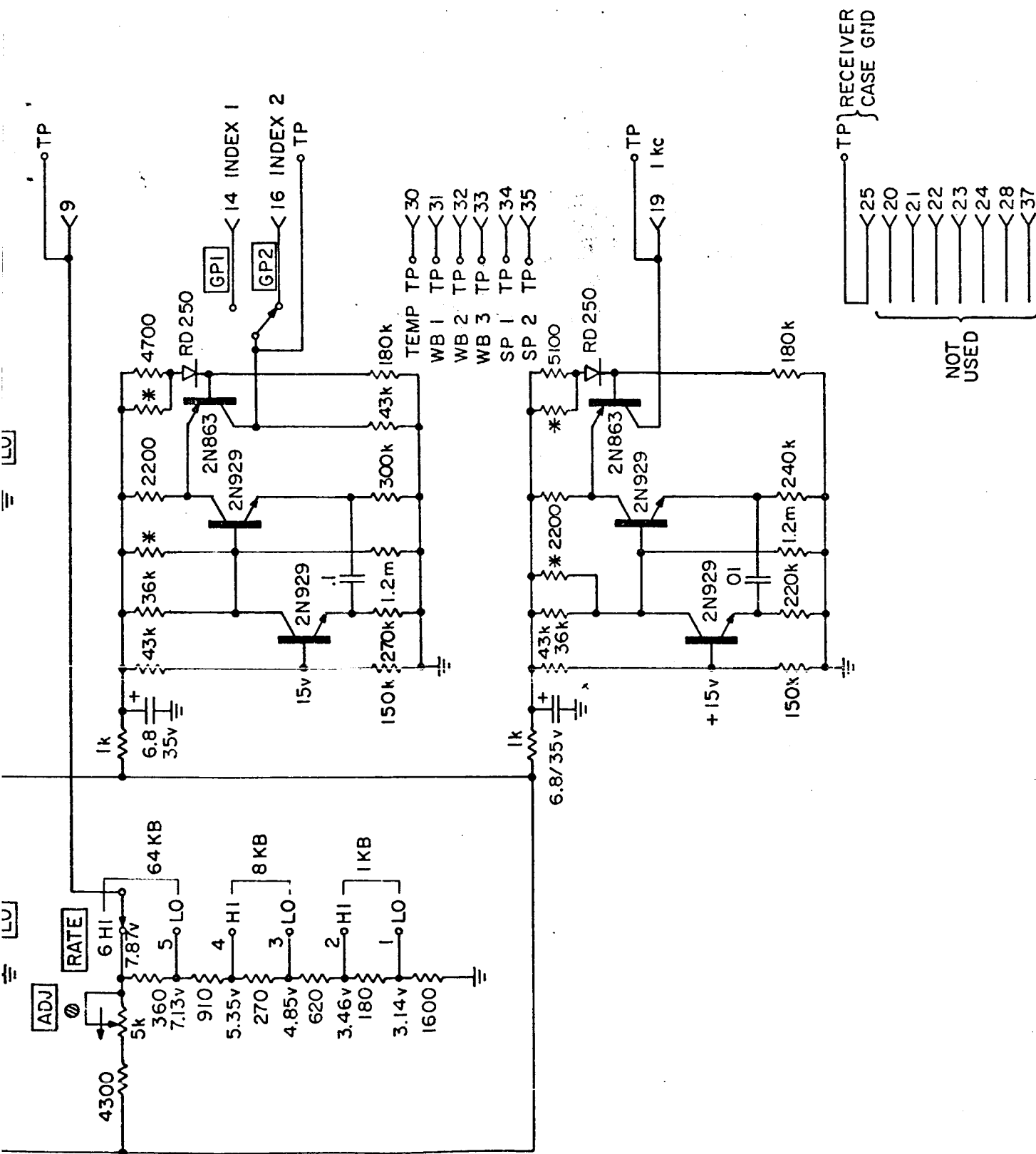


FIG. 8.1 BENCH TEST AND CHECKOUT MONITOR

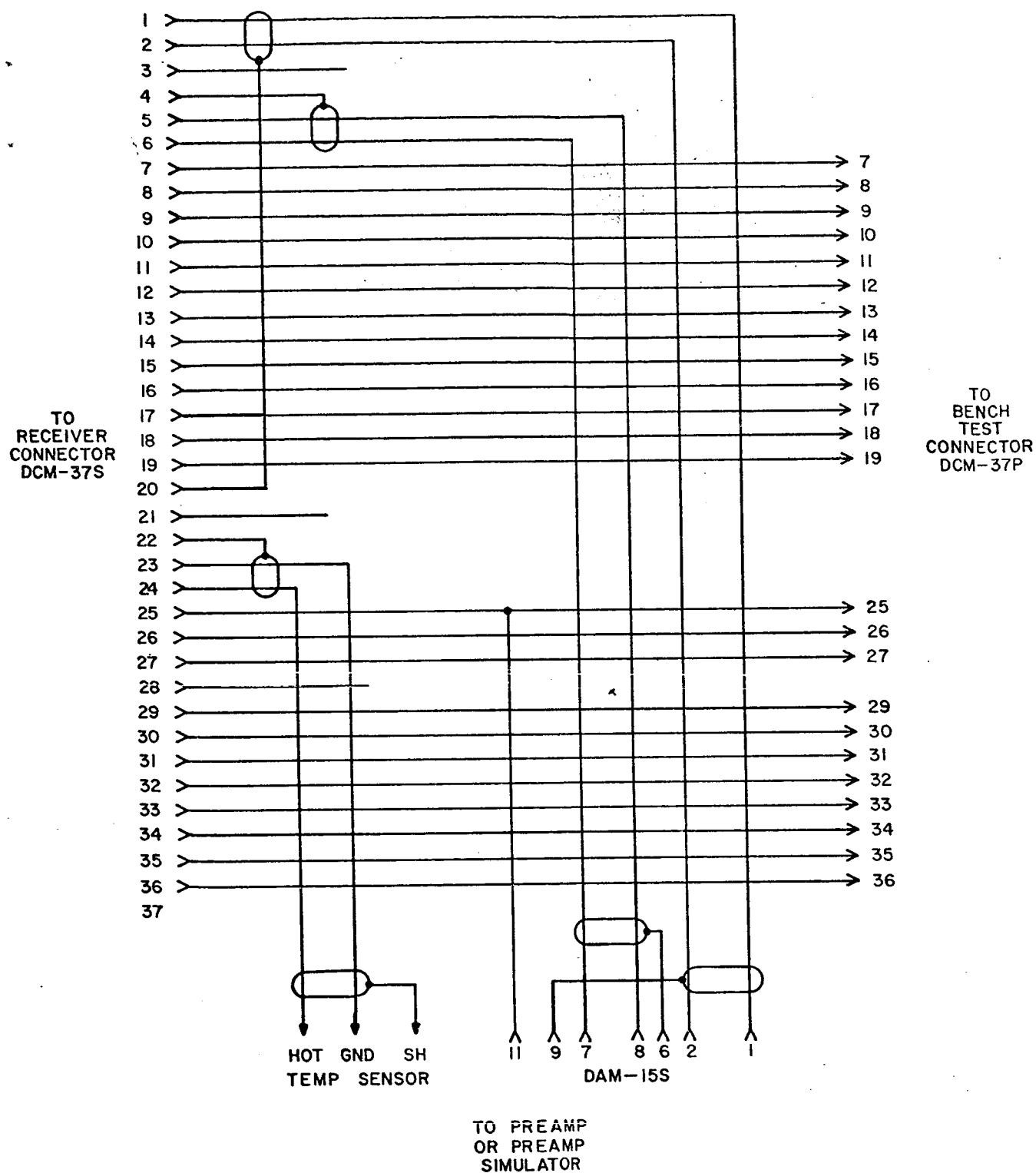
DCM - 37S



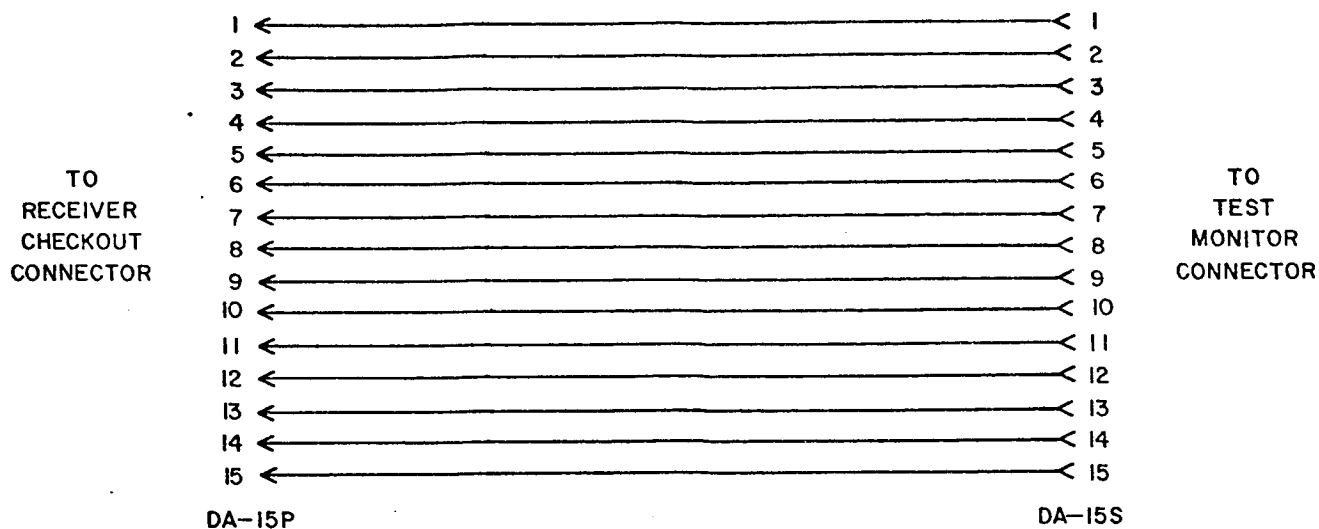


D-4007-6

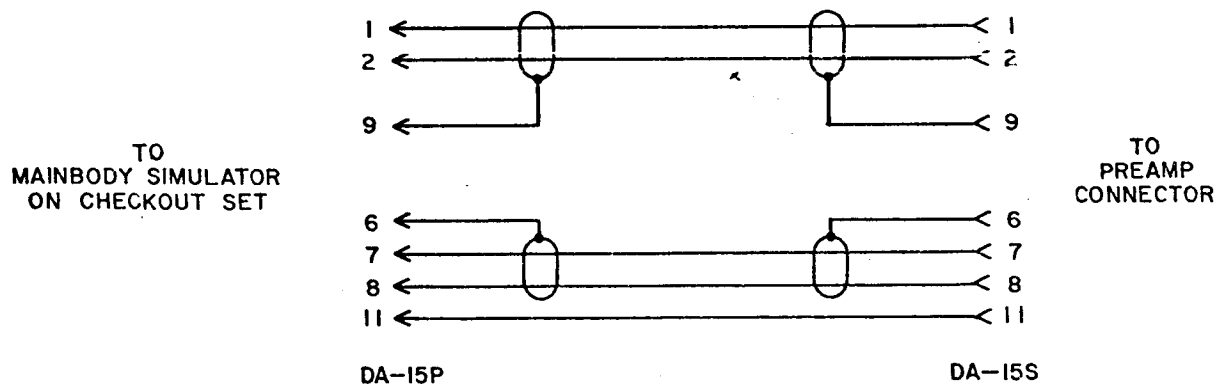
FIG. 8.2 SCHEMATIC DIAGRAM, SPACECRAFT SIMULATOR



RECEIVER BENCH TEST CABLE
(5 FOOT LENGTH)



RECEIVER CHECKOUT MONITOR CABLE
(10 FOOT LENGTH)



PREAMP CHECKOUT CABLE
(5 FOOT LENGTH)

D-4007-3

FIG. 8.3 RECEIVER BENCH TEST CABLE

developed across the $5\ \Omega$ resistor in series with the load. When this voltage exceeds the forward bias of the RD250 diode, current is shunted from the base through the diode, limiting the current available to the load. Further limiting takes place when the current amplifier attempts to draw more current from the reference to overcome that lost in the diode shunt. However, the relatively high impedance of the reference forces the voltage toward zero as more current is drawn. A front panel meter gives an indication of either output voltage or current.

The two regulators supplying the $\pm 20\text{ V}$ to the GSE electronics are simple Zener-diode-referenced emitter followers. Resistors in the collector leads, while acting as current limiters, serve to reduce the power dissipated in the regulating transistors.

8.1.2.2 1-kHz Reference Oscillator

The 1-kHz reference signal used in calibrating the receiver is supplied by an astable, emitter-coupled multivibrator. A current source is gated by the output of the multivibrator. The signal developed at the input to the experiment is a square wave of 5 V amplitude.

8.1.2.3 Index Generator

Index pulses for stepping the experiment receivers in frequency are generated by an astable, emitter-coupled multivibrator. The basic frequency of oscillation is chosen as 110 Hz, corresponding to the spacecraft index rate for high bit rate (64 kb). The output from the multivibrator gates a current source causing a 5-V square wave to appear across the input to the experiment. A single-pole, double-throw switch on the output simulates the selection of the desired one of the two operating equipment groups.

8.1.2.4 Command Circuitry

Impulse commands may be sent to the experiment by energizing the command relay. This relay is of the type used in the spacecraft command receiver in order to duplicate contact resistance and contact bounce found in the actual flight unit. The relay circuit is a one transistor one-shot with a pulse duration of approximately 50 ms, the

duration being governed by the charging rate of the 1- μ F capacitor through the 43-k Ω resistor. Voltage surge protection for the transistor is provided by a clipping diode across the relay coil. Because of the large current drawn when activated, this circuitry is isolated from the main supply by an emitter-follower regulator. A rotary switch and push-button on the front panel select and actuate the commands. Commands labeled 1 through 4 correspond to Impulse Commands 16 through 19, respectively.

8.1.2.5 Telemetry Operational Status Circuitry

Signals normally supplied by the wideband data-handling system to indicate the operating equipment group and bit rate are supplied by three sets of front panel switches. These switches, labeled SWITCH, MODE, BIT RATE, GP1, and GP2, select taps on resistive voltage dividers set to the low and high limits specified for each signal. The dividers are supplied from the ± 20 -V supply; each contains a trimmer to compensate for power supply variations from unit to unit.

8.1.2.6 Test Points

A field of binding posts is provided to allow for monitoring the signals supplied to the experiment and the various outputs from each receiver in the experiment.

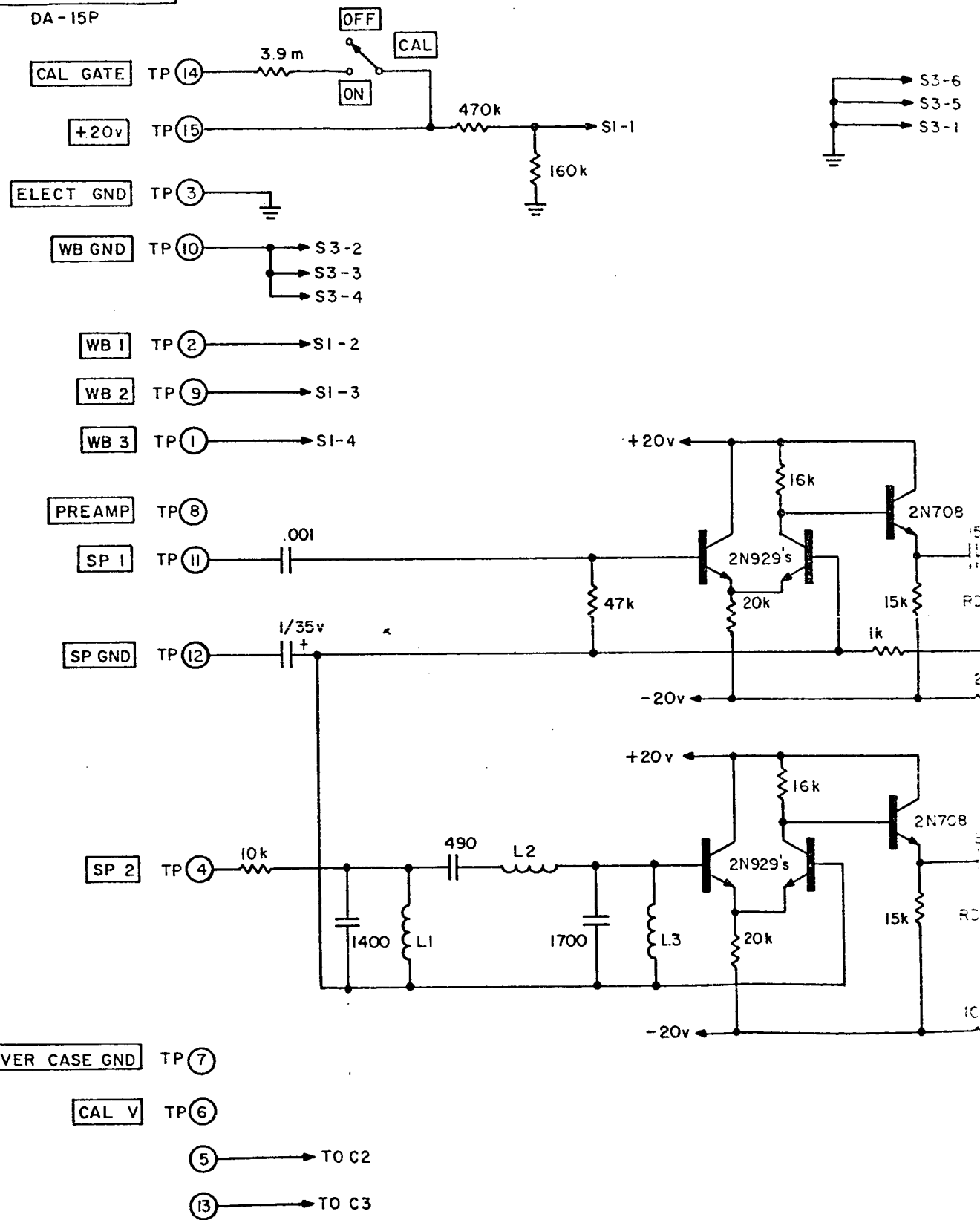
8.1.3 Checkout Monitor (Fig. 8.4)

8.1.3.1 Meter Circuit

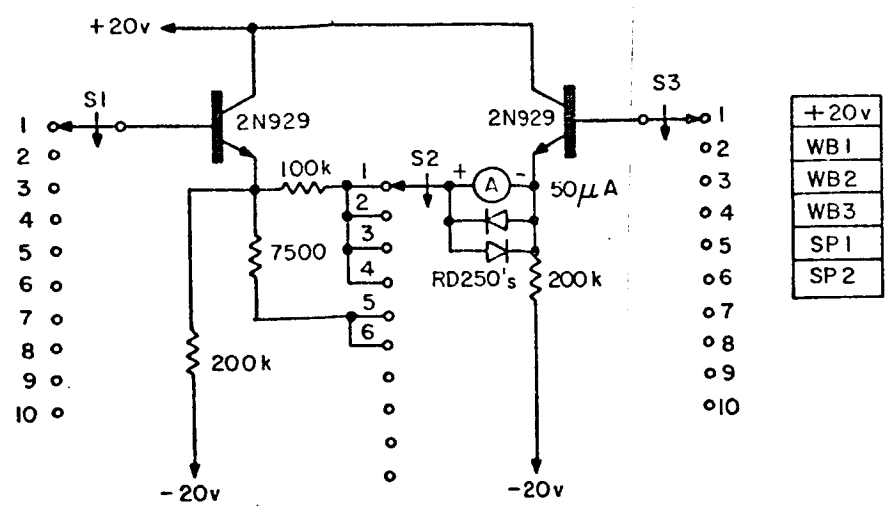
A front panel meter provides for the observation of six signals as selected by a rotary wafer switch located to the left of the meter. The meter is connected between the emitters of a differential emitter-follower. The full-scale range of the meter is varied by changing the resistance in series with the meter. In the first four positions of the switch (+20 V, WB1, WB2, WB3), the meter circuit is connected to the dc output from the experiment. The last two positions (SP1 and SP2) connect the meter to the outputs of the discriminators for the special-purpose outputs from the experiment.

RECEIVER CHECKOUT

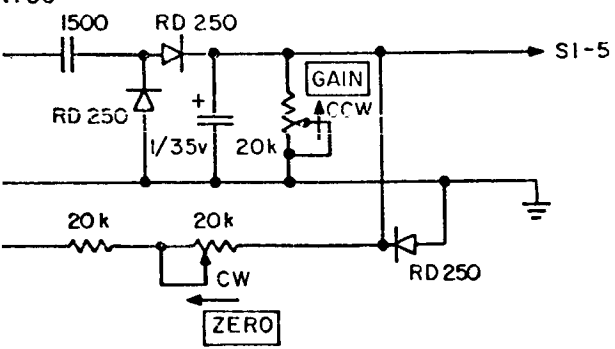
DA-15P



3-6
3-5
3-1

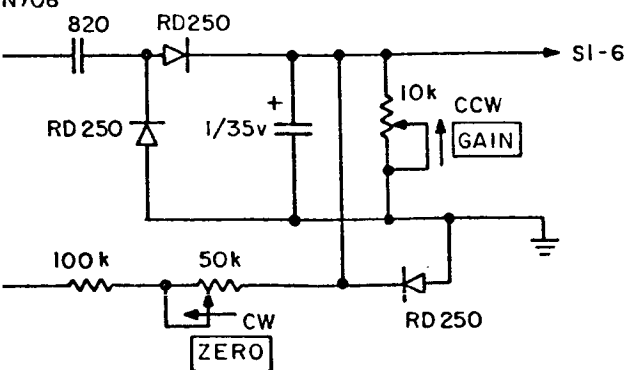


1708



COIL DATA	
CORE:	6565IN28A250
BOBBIN:	1 SECTION
L1	445 ^T # 37 HF
L2	750 ^T # 39 HF
L3	403 ^T # 37 HF

N708



D-4007-8

FIG. 8.4 SCHEMATIC DIAGRAM, CHECKOUT MONITOR

8.1.3.2 Discriminators

Two frequency discriminators have been included in the check-out monitor to provide a means for displaying the information contained on the frequency-modulated special-purpose channels. The discriminator designated SP1 is used to demodulate the 30-kHz VCO, which occupies IRIG channel 15. The second discriminator is used to demodulate the local oscillator of the Band 2 sweeping receiver. A bandpass filter is used to extract the local oscillator of the second sweeping receiver from the composite waveform designated Special Purpose Channel 2. The filter is a three-pole, equal-ripple filter with a bandpass from 13.7 to 25.5 kHz.

Both discriminators are of the same design comprising a long-tail pair clipper and emitter follower that drive the cycle counter type discriminator circuit. The output is filtered and provides a positive-going dc output. The output excursion and zero are set by two potentiometers accessible from the front panel. The outputs of these discriminators may be switch selected for display on the monitoring meter.

8.1.3.3 Calibration Gate

A front panel switch is provided to energize the calibrator by bypassing the receiver's internal calibration oscillator gating circuit. This enables the calibration signals to be observed at the convenience of the operator. The circuit comprises a single-pole switch which connects the internal calibration gate to the receiver's regulated power supply through a 3.9-M Ω resistor.

8.1.3.4 Test Points

A field of binding posts is provided to allow the use of external instruments for the viewing and measuring the signals brought from the experiment through the test connector.

8.1.4 Preamplifier Simulator (Fig. 8.5)

The circuitry of the preamplifier simulator is identical to that used in the flight preamplifier. This circuit has been included in the Bench Test GSE to allow the main-body package of the experiment to be

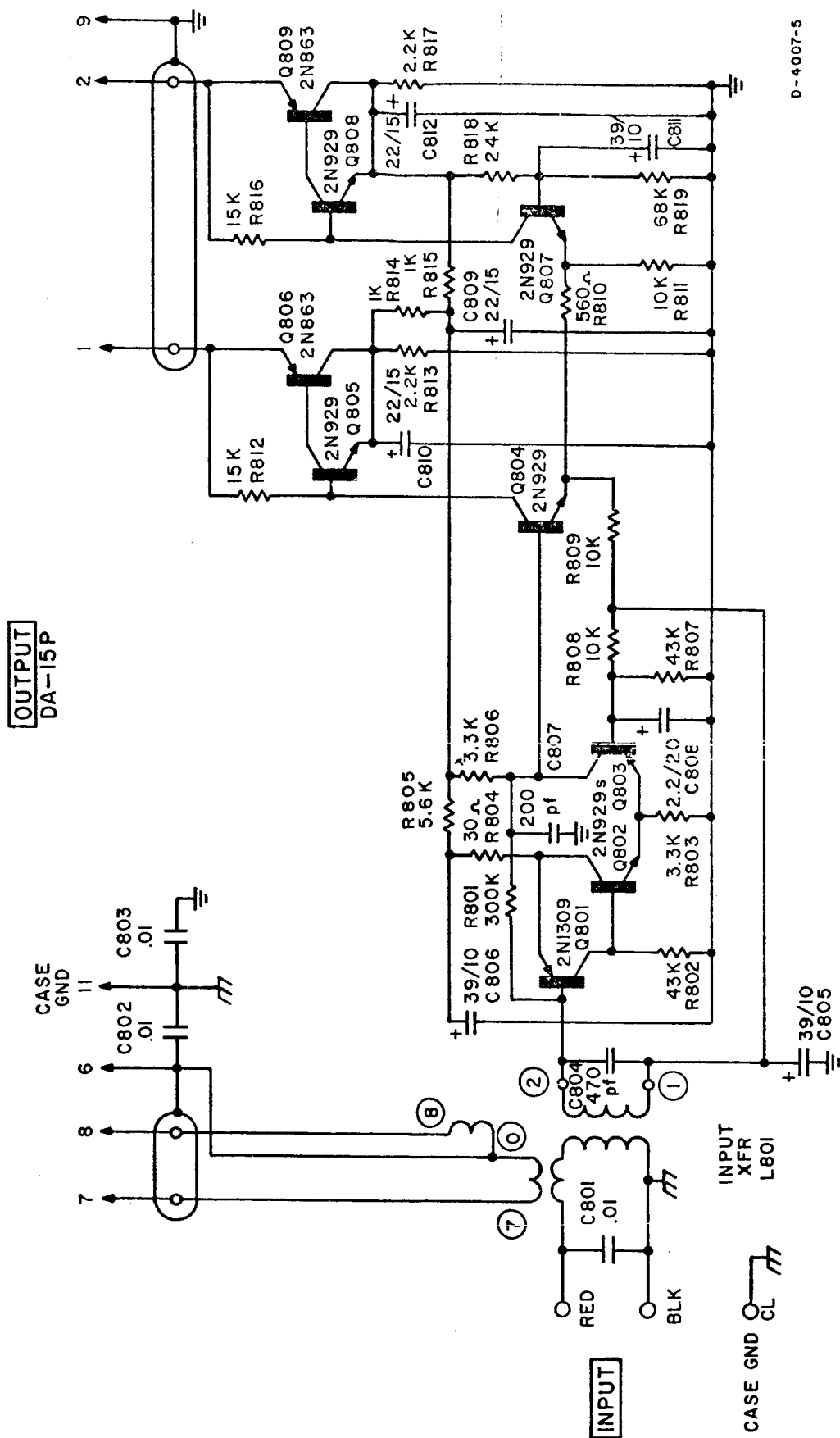


FIG. 8.5 SCHEMATIC DIAGRAM, PREAMPLIFIER SIMULATOR

checked out without the need for the flight preamplifier, which is mounted in EP-5, and sometimes not available. The case surrounding the preamplifier simulator is insulated from the front panel to allow the case to be grounded to an appropriate ground. Power for the circuit is provided by the main-body package through the interconnecting cable as it would be in actual flight configuration. The interconnecting cable has been made sufficiently long to simulate the boom cables on the spacecraft.

8.1.5 Main-Body Simulator for Preamp Test (Fig. 8.6)

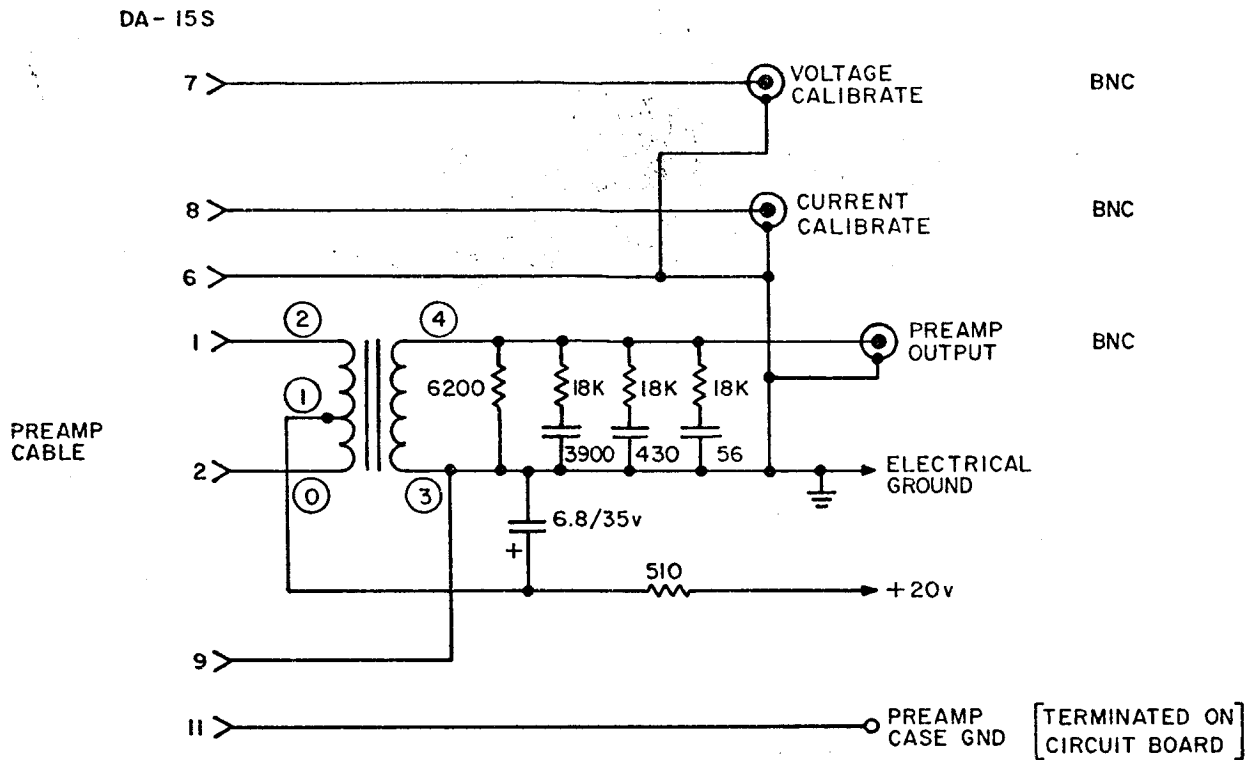
The Main-Body Simulator is used to check the performance of the flight preamplifiers without the benefit of the main-body portion of the experiment. In addition to presenting the proper load to the preamplifier under test, power is supplied to the preamplifier from the GSE +20-V supply. BNC connectors on the front panel permit the injection of voltages and currents for calibrating the response of the preamplifier. The output of the preamplifier is provided by a BNC on the front panel.

8.2 STIMULUS AND IST SET

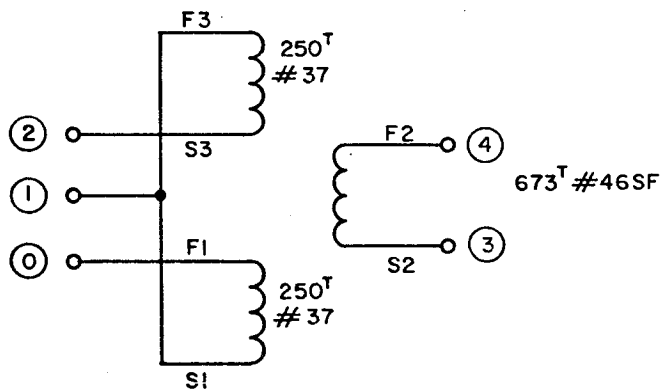
8.2.1 Introduction

The Stimulus and IST Ground Support Equipment is a portable, battery-powered unit designed for use as a signal source for checking and calibrating the response of the experiment package. In addition, the GSE includes a monitoring set for converting a portion of the experiment's frequency-modulated special-purpose data into signals that can be displayed on strip-chart recorders during Integrated Systems Tests (IST). The stimulus portion includes an oscillator and an attenuator. Included in the IST monitor is a discriminator, tuned detector, and test field.

The unit occupies a standard 19-inch relay rack panel (Fig. 8.7) mounted in and insulated from a Zero equipment case for mechanical protection and electrical isolation. To reduce the interaction of the various circuits, the electronics are contained in a compartmentalized chassis box mounted on the front panel.



COIL DATA:
#65 N28 OL 1-SEC



WIND IN ORDER: 1, 2, 3

FIG. 8.6 MAIN-BODY SIMULATOR FOR PREAMP TEST

8.2.2 Stimulus Source (Fig. 8.8)

8.2.2.1 Oscillator

The oscillator uses an astable, emitter-coupled multivibrator whose frequency of oscillation is determined by six switch selected capacitors. The frequencies (0.240, 1.600, 1.410, 12.00, 11.00, and 100.6 kHz) are chosen to coincide with the band edges of the three stepping receivers in the experiment. A continuously variable vernier provides a deviation of ± 13.5 percent from the center frequency to allow for variations between receivers. Emitter followers are used to feed the switching transistors to reduce the circuit's dependence upon temperature, aging, and voltage variations. The output of the multivibrator is used to gate a current generator. The signal output to the attenuator is a 500- μ A square wave. A Zener diode reference source and junction compensating silicon diode combine to maintain the output signal amplitude. The electronics have been allowed to float with respect to ground to allow a greater flexibility in grounding arrangements.

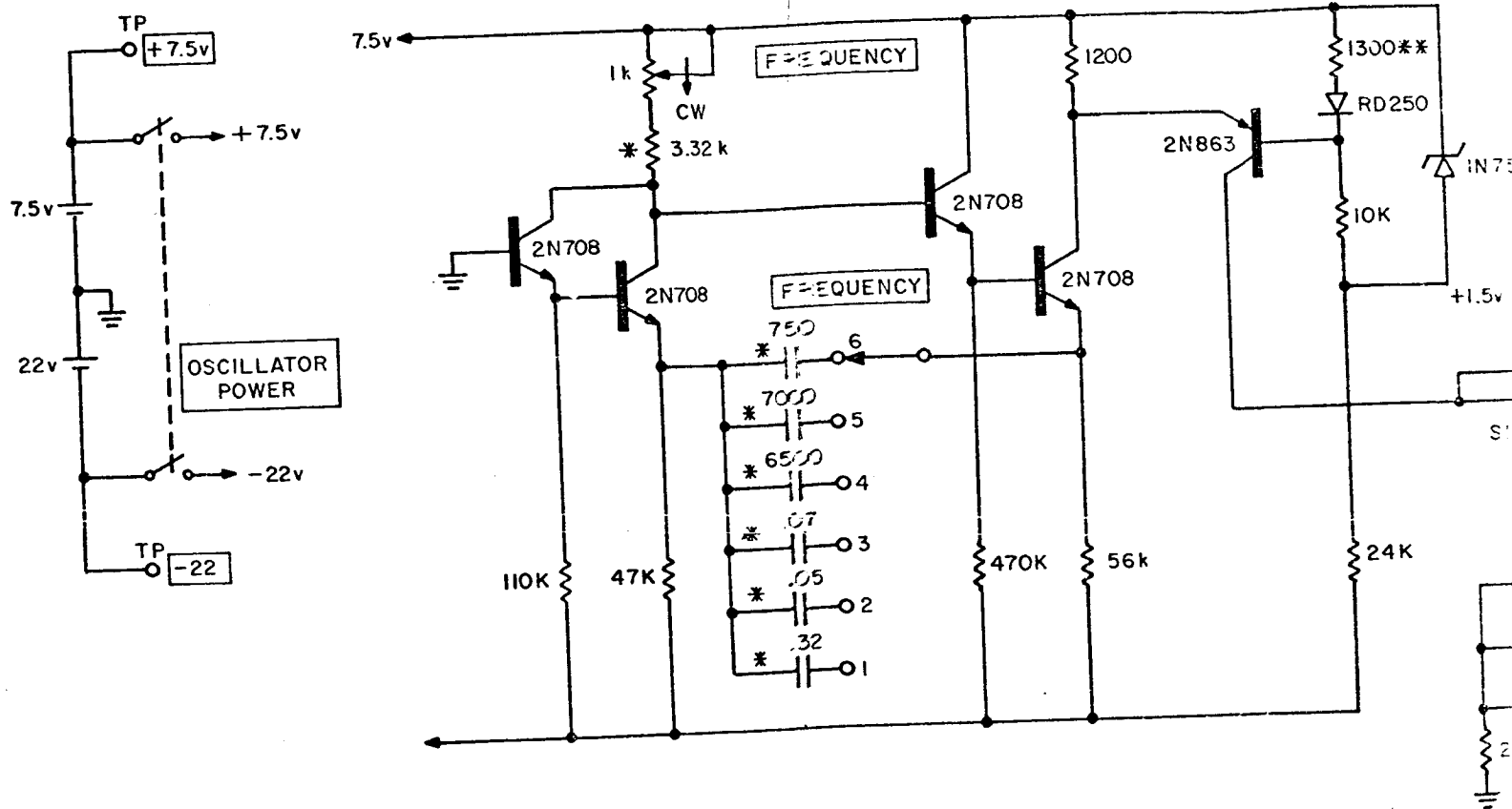
8.2.2.2 Attenuator

The attenuator is composed of two parts. The first, a 0-to-100-dB unit, has steps of 20 dB each. Shielded from the first part, the second has a range of 0 to 20 dB in 5-dB steps. Both sections use 5 percent carbon resistors, which determine the accuracy of the attenuator. Since the attenuator carries the dc component of the output current generator, a 100- μ F capacitor is used to decouple the output.

8.2.3 IST Monitor (Fig. 8.9)

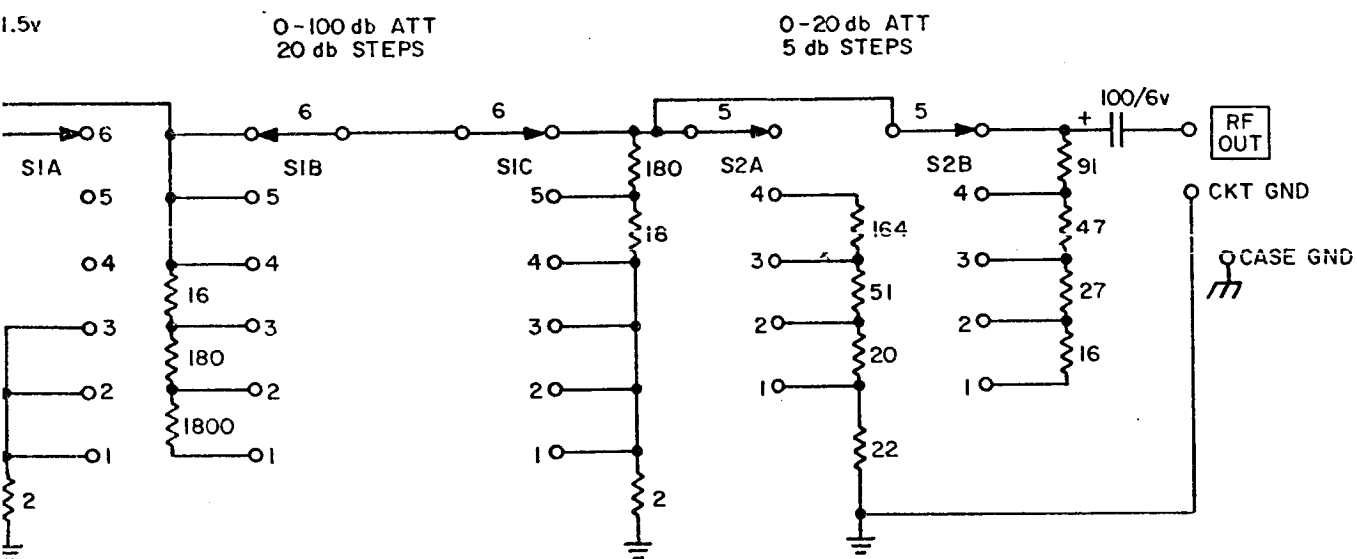
8.2.3.1 Local Oscillator Discriminator

The frequency discriminator contained in the monitor set is designed to operate on the local oscillator of the second stepping receiver which is transmitted as part of the special-purpose telemetry data. The input to the discriminator may be switch selected as the output of the experiment received taken through the test connector or through the special-purpose telemetry receiver in the recording van. The selected signal from the switch is then fed to an isolating



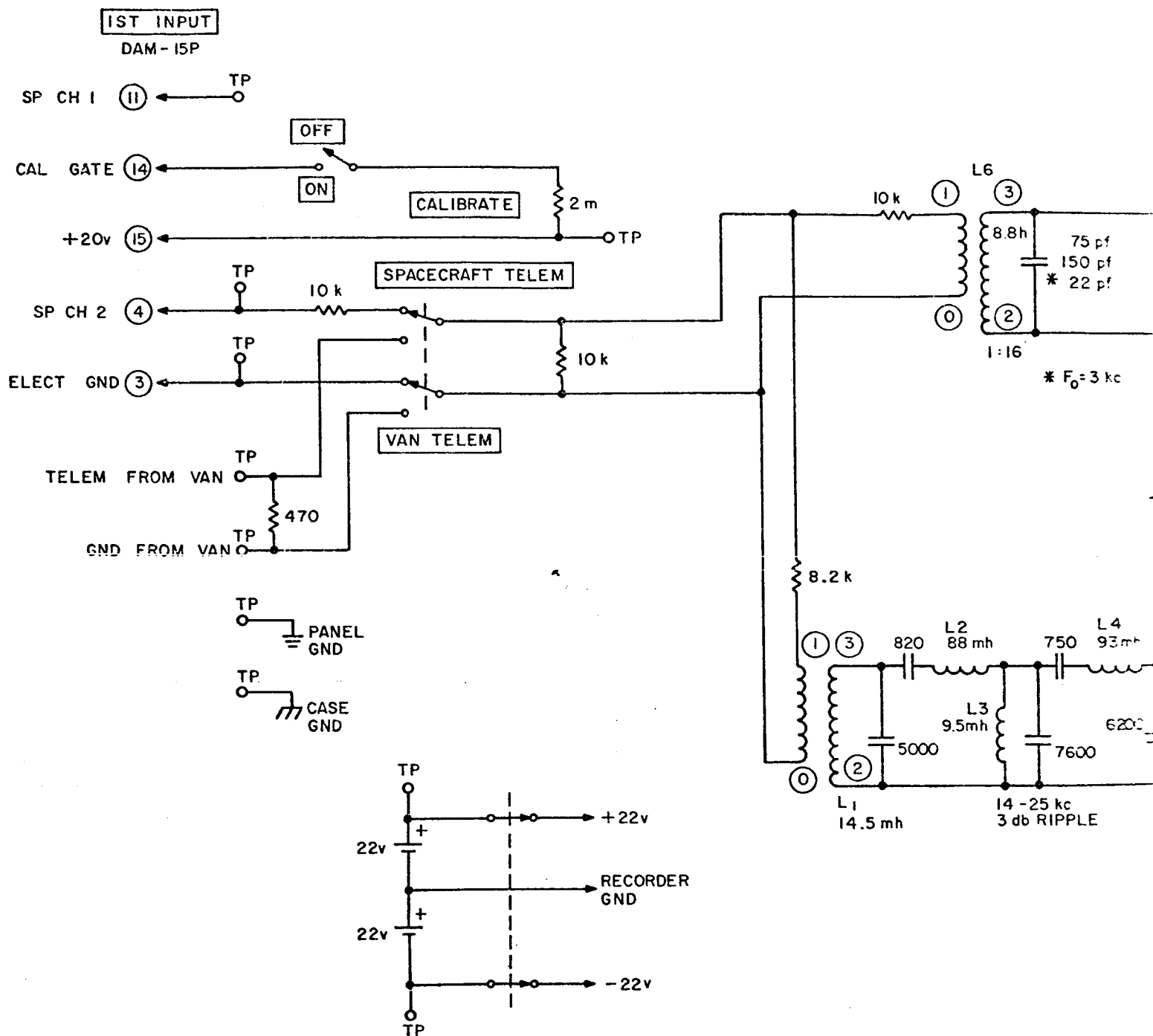
* NOMINAL VALUE SHOWN
 EXACT VALUE CHOSEN FOR DESIRED RANGE
 ** SELECTED FOR 500μa MINIMUM CURRENT IN OUTPUT TRANSISTOR

IN754



D-4007-4

FIG. 8.8 SCHEMATIC DIAGRAM, STIMULUS SOURCE



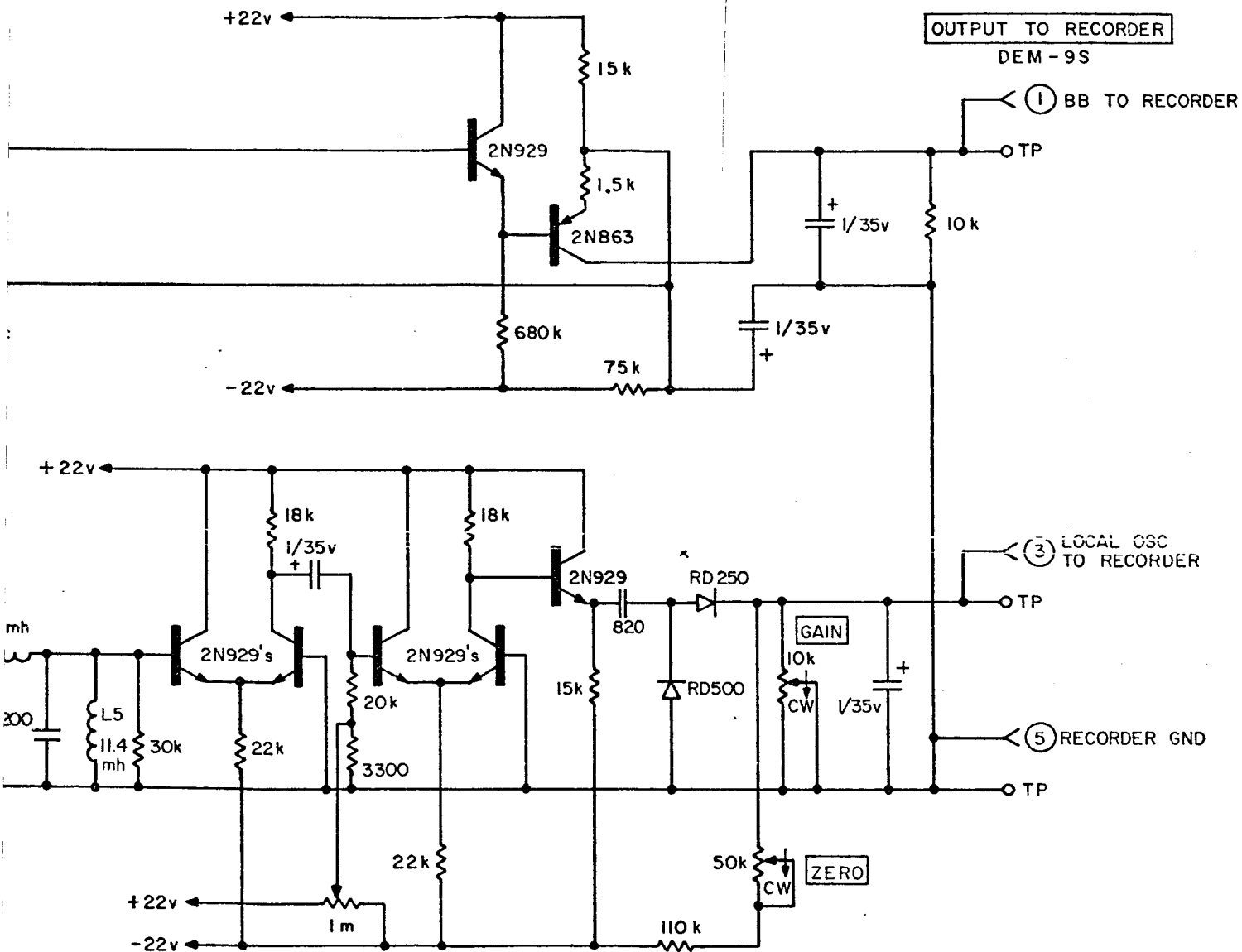


FIG. 8.9 SCHEMATIC DIAGRAM, IST MONITOR

transformer, which forms the input branch of a five-pole, 3-dB equal-ripple bandpass filter. The bandpass of 14-25 kHz is chosen to eliminate the 0.3-12.5-kHz broadband frequency spectrum and the 53-kHz IF, which are also present in Special Purpose Channel 2.

Following the filter are two cascaded clipping amplifiers. The bias on the second stage is adjustable through a trimmer for symmetrical clipping. The output of the clippers drives an emitter follower, which feeds the cycle-counter-type discriminator circuit. Output zero setting and signal excursion are adjustable by the two potentiometers located on the front panel. The circuit is powered by two 22-1/2-V batteries and is grounded only at the recorder ground.

8.2.3.2 Tuned Detector

The tuned detector, like the local oscillator discriminator, receives its input from the selector switch. An isolating transformer, acting as a current source, couples the signal into a single-tuned parallel-resonant circuit. The circuit is resonant at 3 kHz, which is the third harmonic of the experiment's calibration oscillator. Whenever a 3-kHz signal is present in the special-purpose telemetry data, specifically in the broadband receiver's frequency spectrum output during a calibration sequence, voltage will appear across the resonant elements. An emitter follower samples the signal developed. Because of the transistor's high-input impedance in this configuration, the tuned circuit's resonant Q is affected only slightly. The emitter follower drives a current amplifier operating in Class C, which conducts during the negative half cycle of the input signal. The rectified signal thus obtained is capacitively filtered and fed to the strip-chart recorder. Power for the circuit is obtained from the same batteries that supply the discriminator.

8.2.3.3 Calibration Gate

A front panel switch is provided for turning the receiver's internal calibration oscillator on. Closing the switch connects a 2-M Ω resistor from the receiver's regulated power supply to the gate controlling the oscillator, energizing the latter. This function is

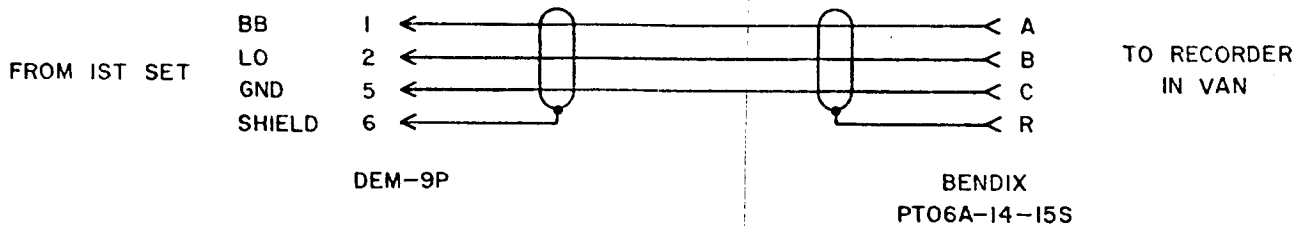
only available if connection is made to the experiment package through the test connector and the input of the GSE labeled IST INPUT.

8.2.3.4 Test Points

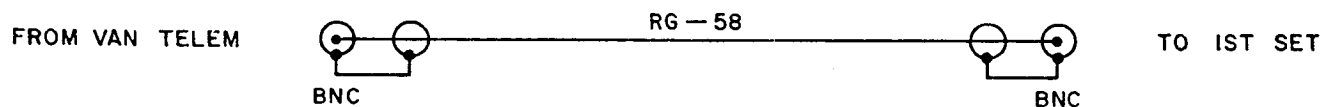
A field of binding posts is provided to allow the monitoring of the outputs of the GSE circuitry. Additional binding posts provide convenient connection points for the panel and GSE case grounds. When the experiment is connected to the GSE via the IST INPUT, the +20-V power supply, SP 1, and SP 2 may be observed with respect to ELECTRICAL GROUND on binding posts bearing those designations. Pin jacks are provided for monitoring the state of the batteries used in the GSE.

8.2.3.5 Checkout and IST Cables

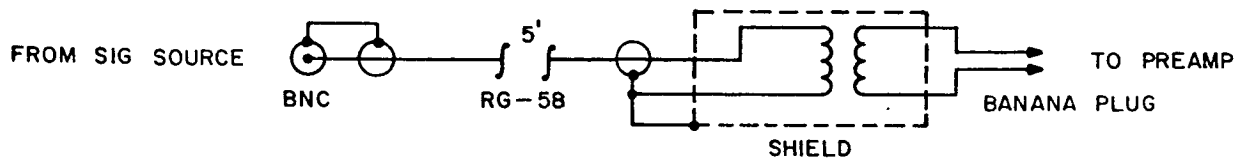
Schematics are shown in Fig. 8.10 for recorder, IST telemetry, and dummy antenna cables.



RECORDER CABLE FOR IST
(30 FOOT LENGTH)



IST TELEMETRY CABLE
(60 FOOT LENGTH)

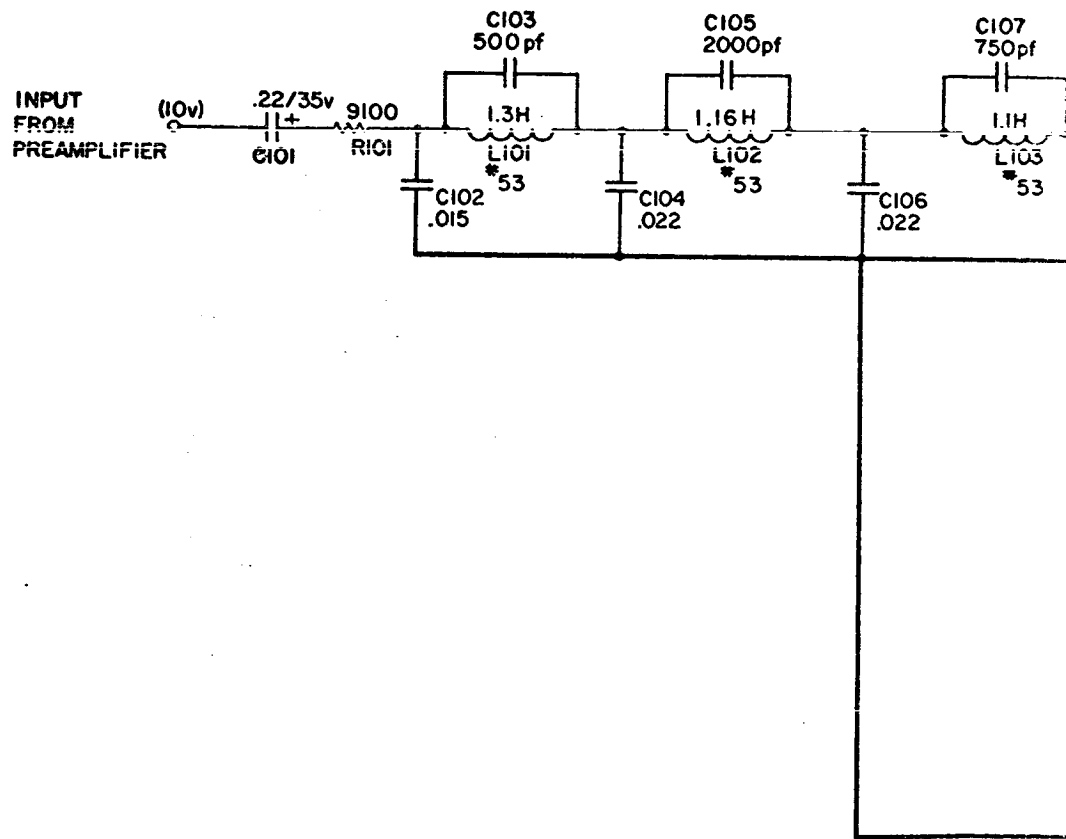


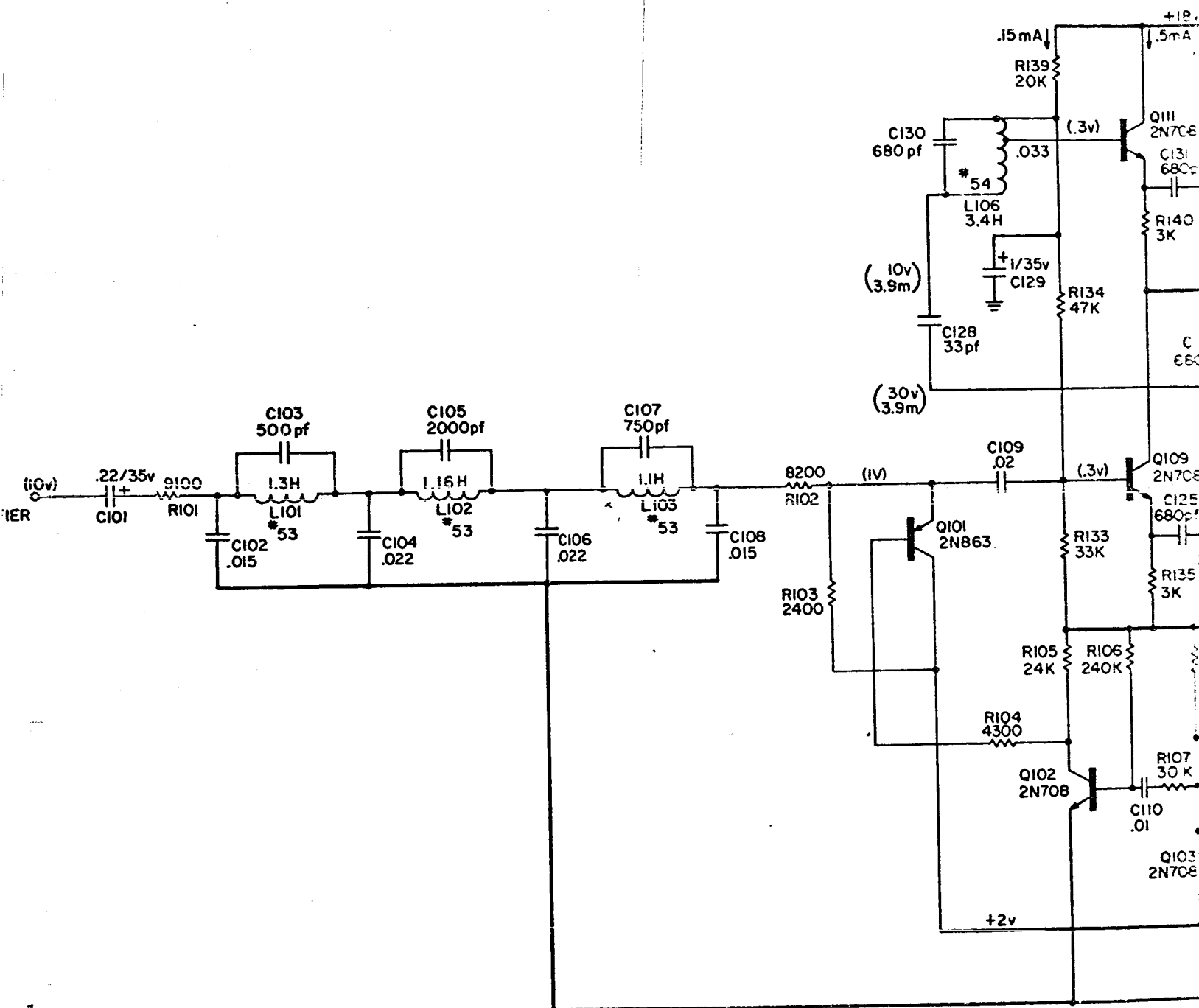
DUMMY ANTENNA CABLE

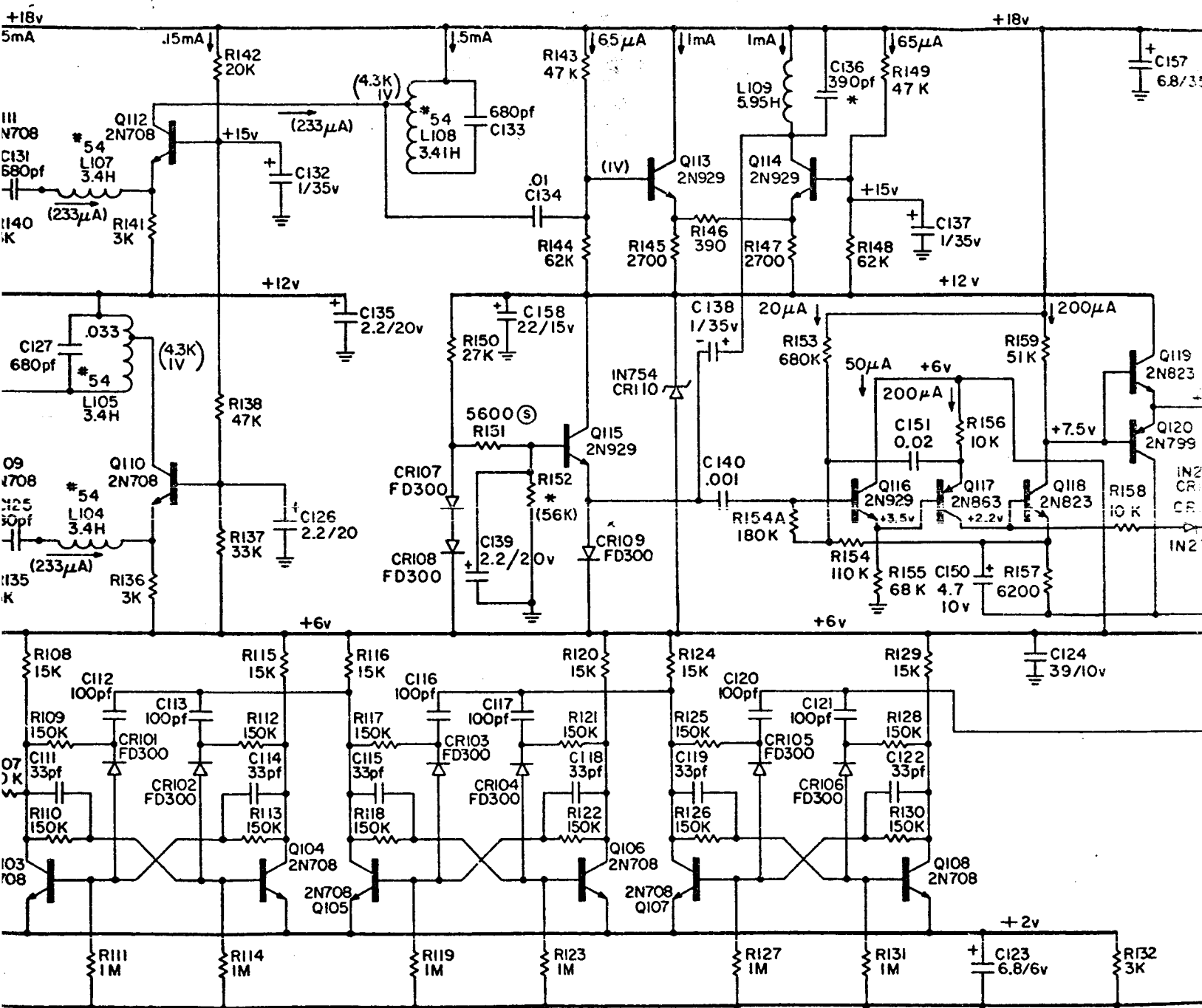
FIG. 8.10 CHECKOUT AND IST CABLES

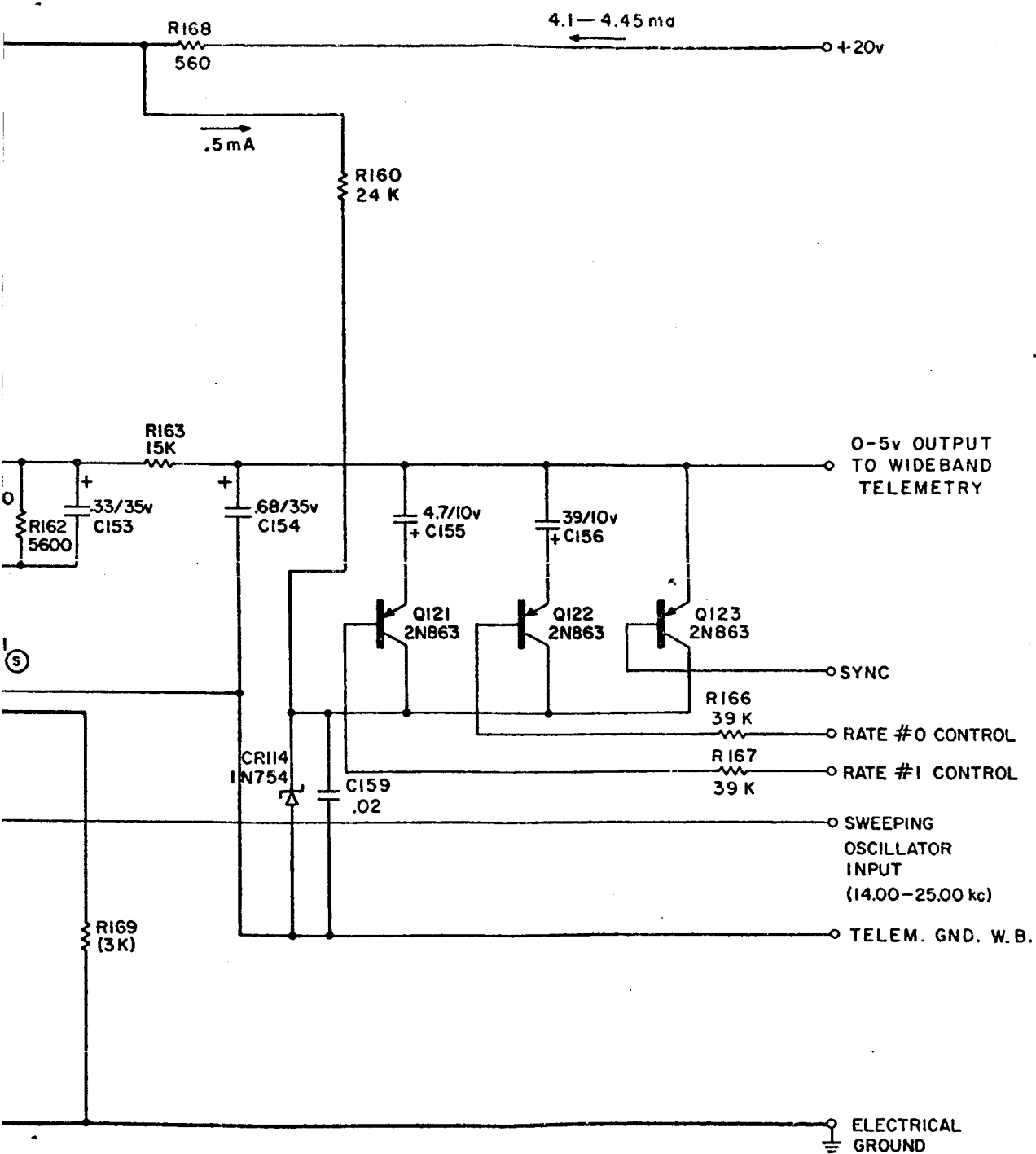
D-4007-2

Appendix A
EXPERIMENT SCHEMATICS





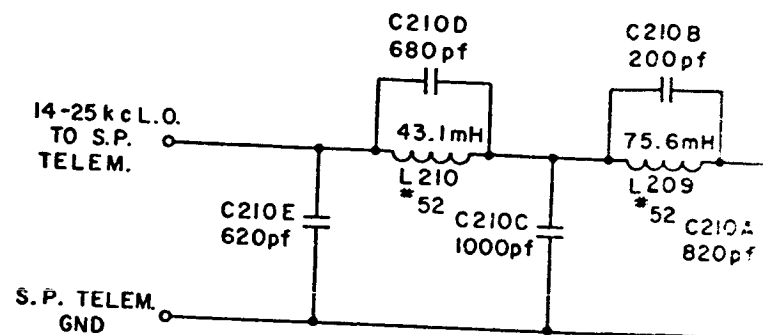
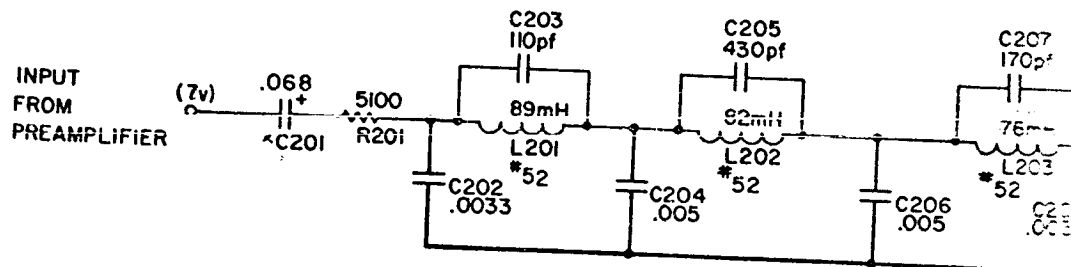


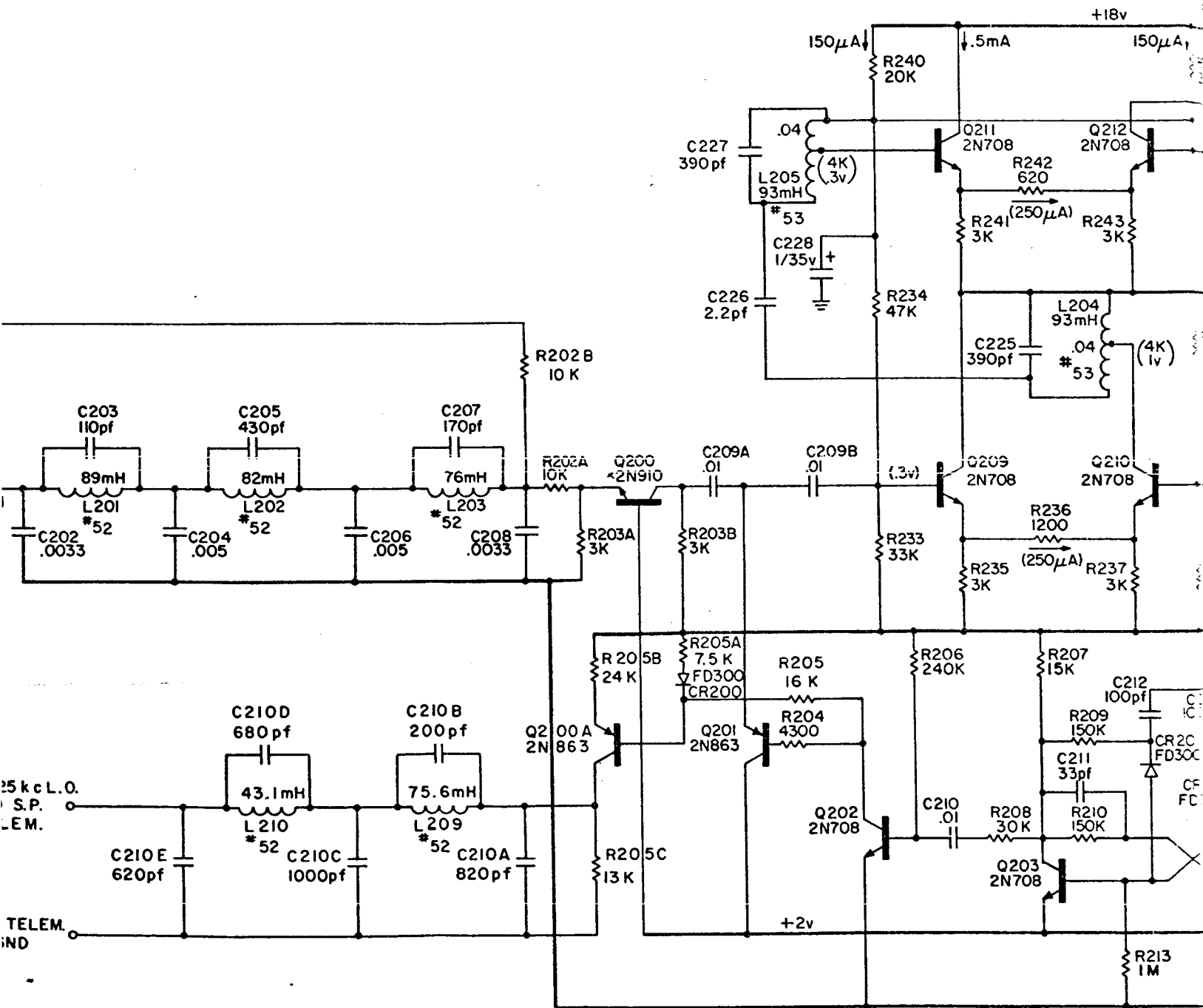


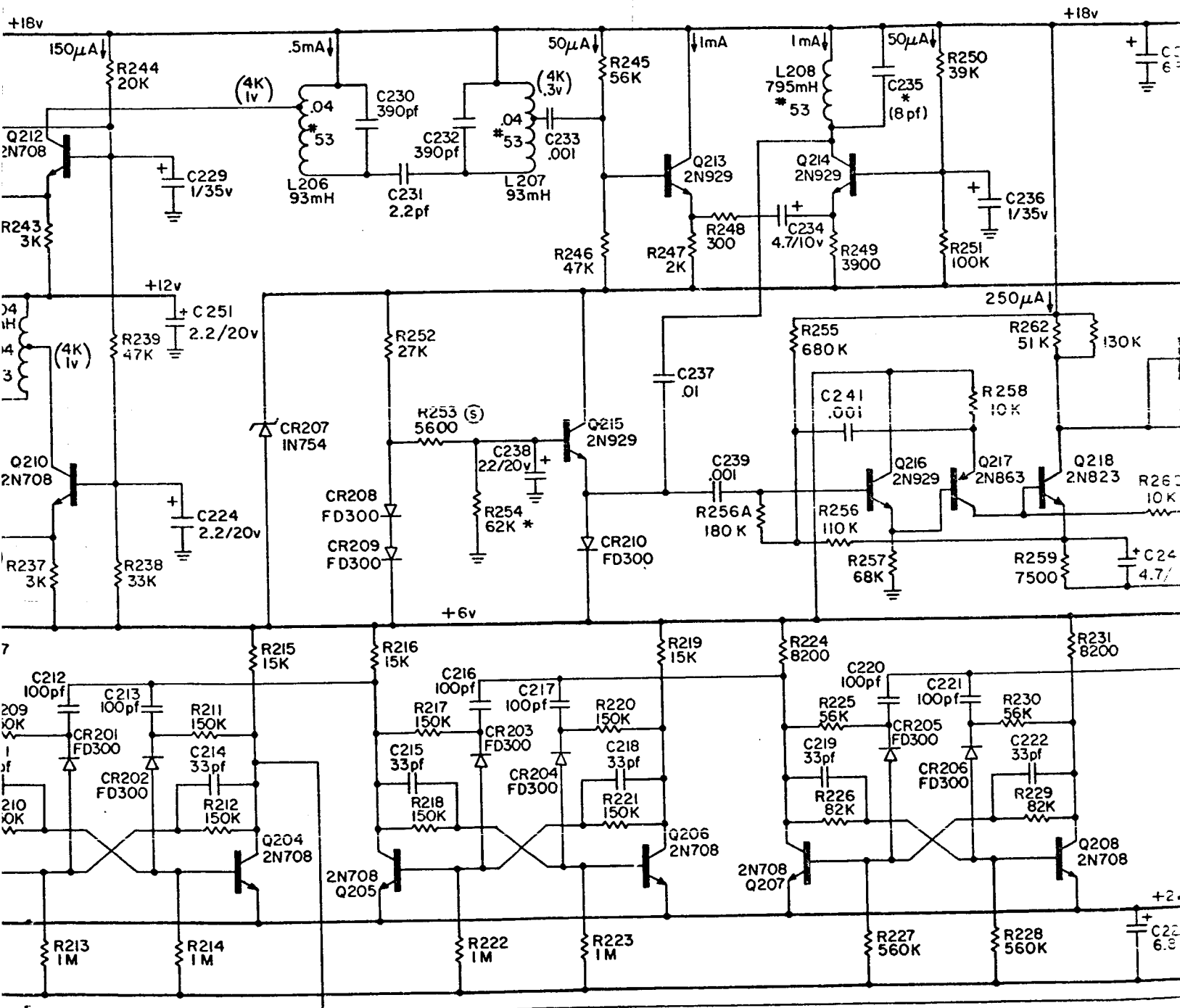
D-4007-34

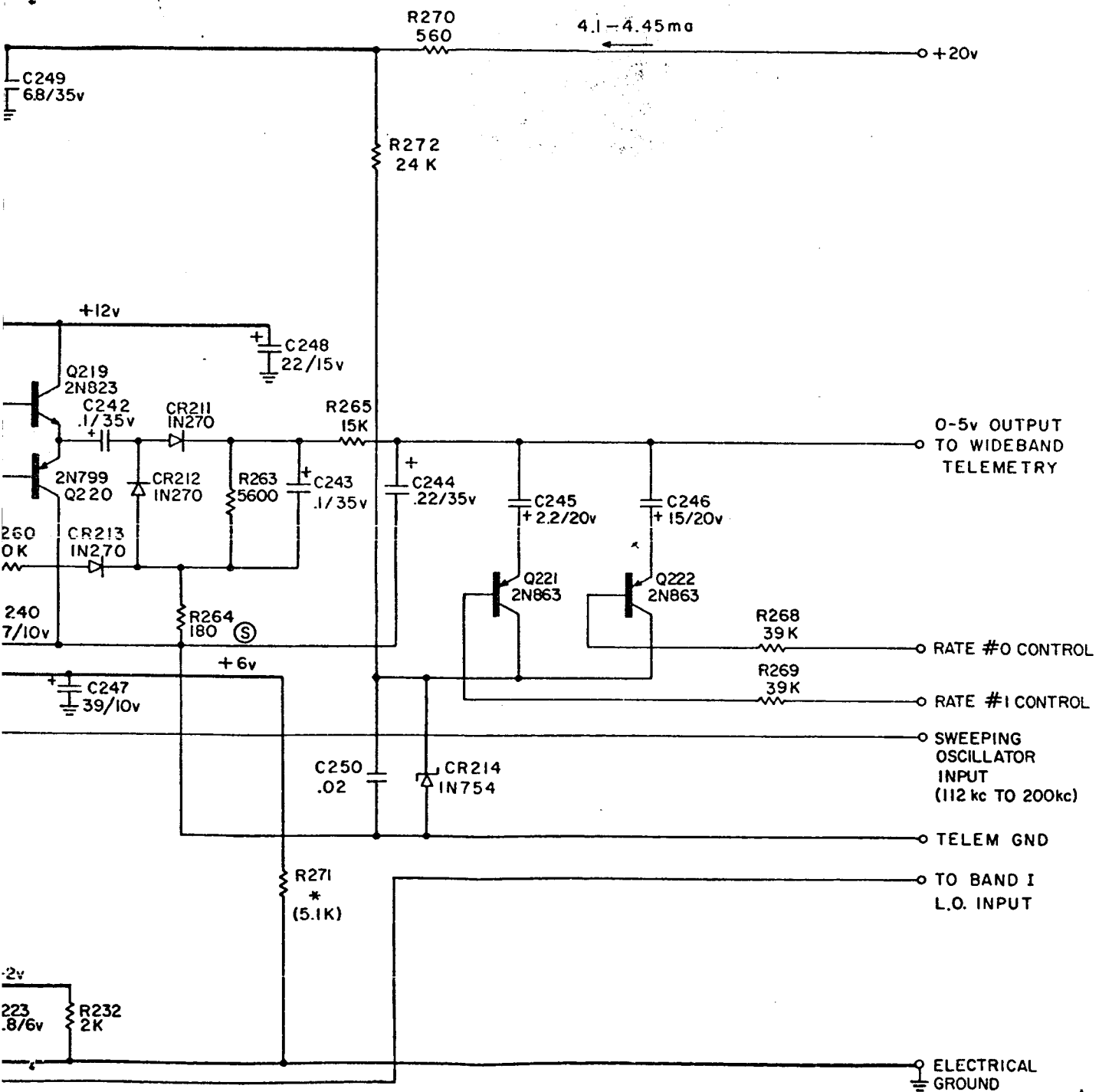
FIG. A-1 MODULE 1, BAND 1 RECEIVER

TO LOG
AMPLIFIER



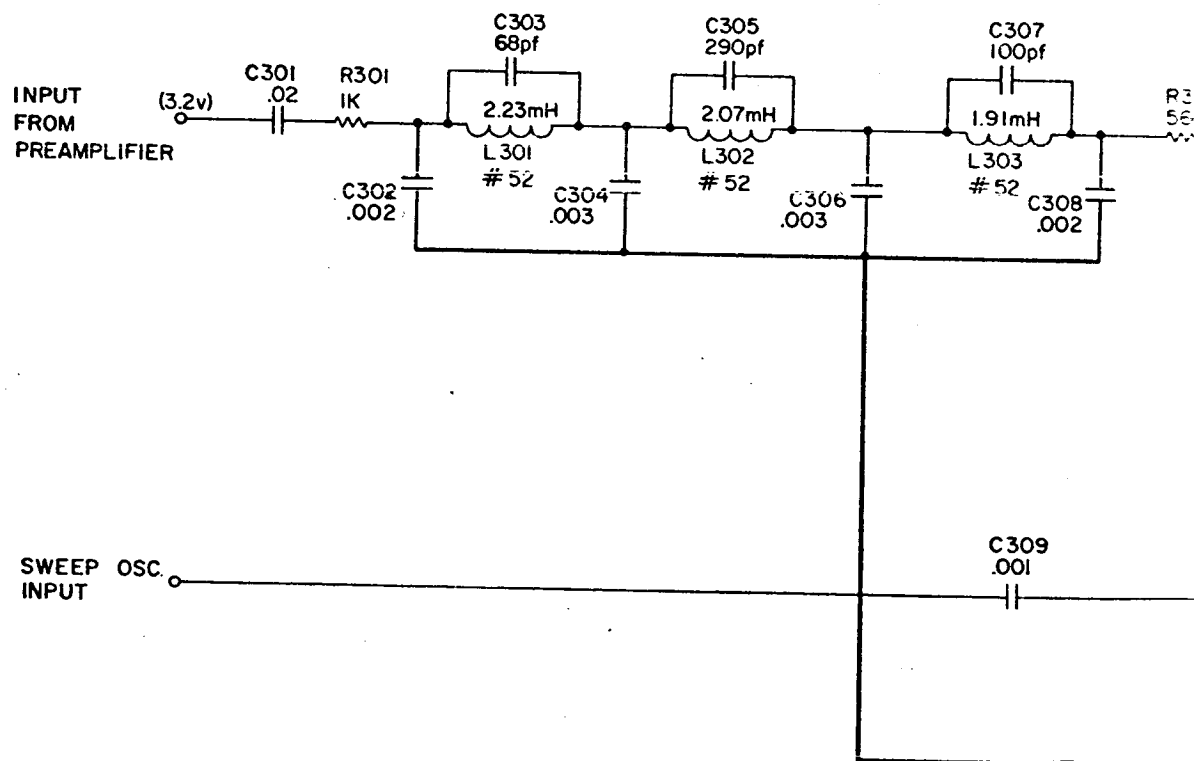


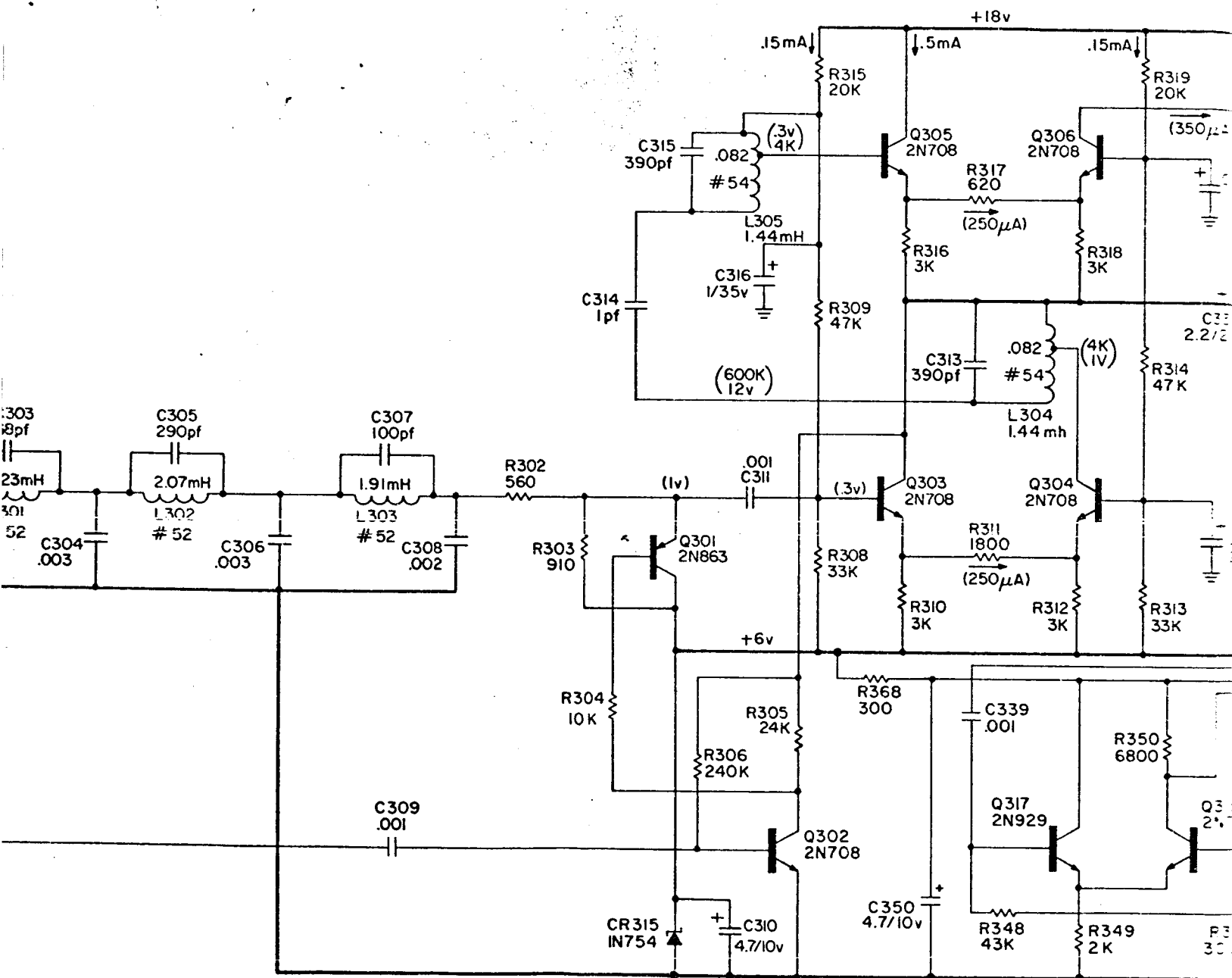


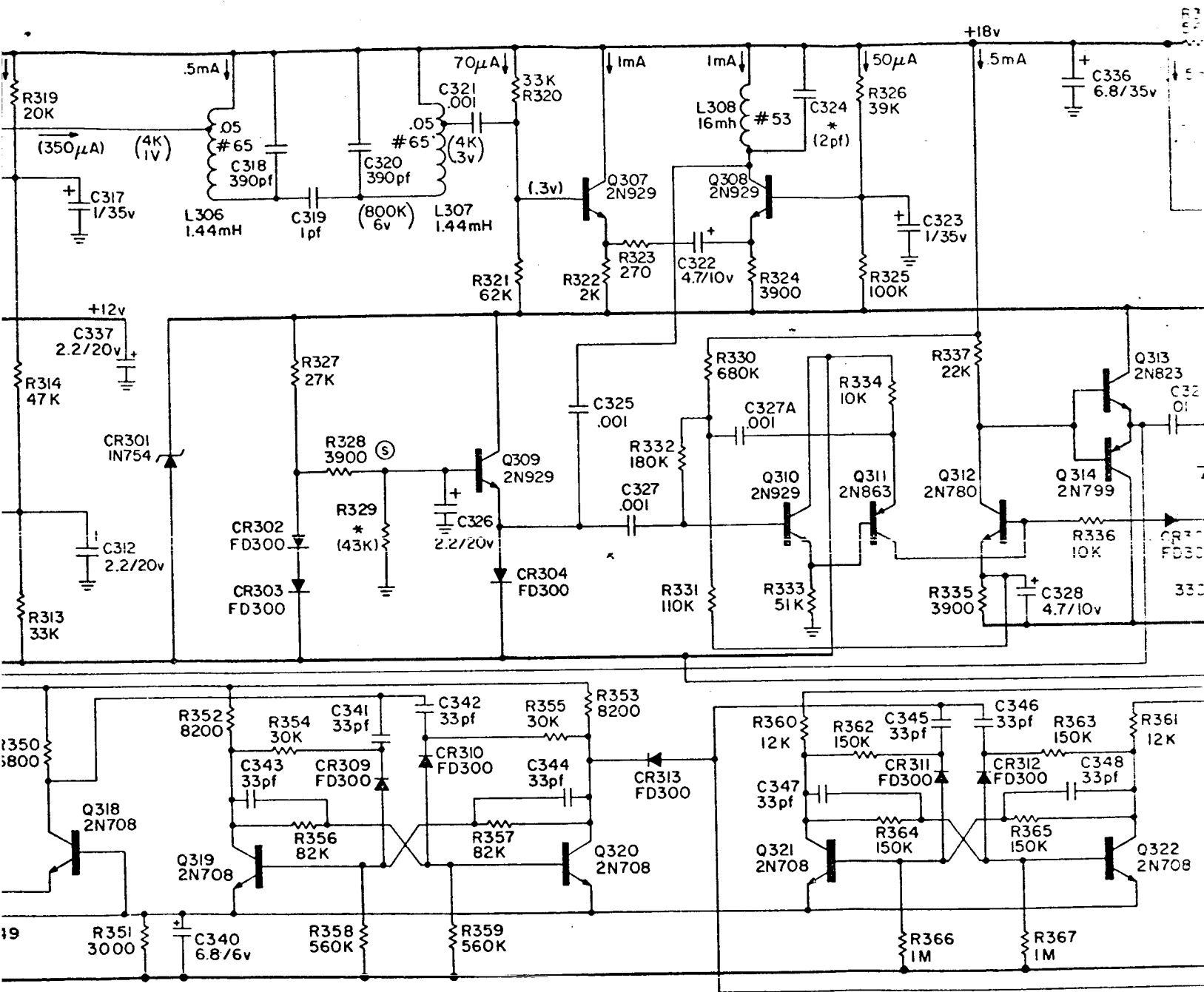


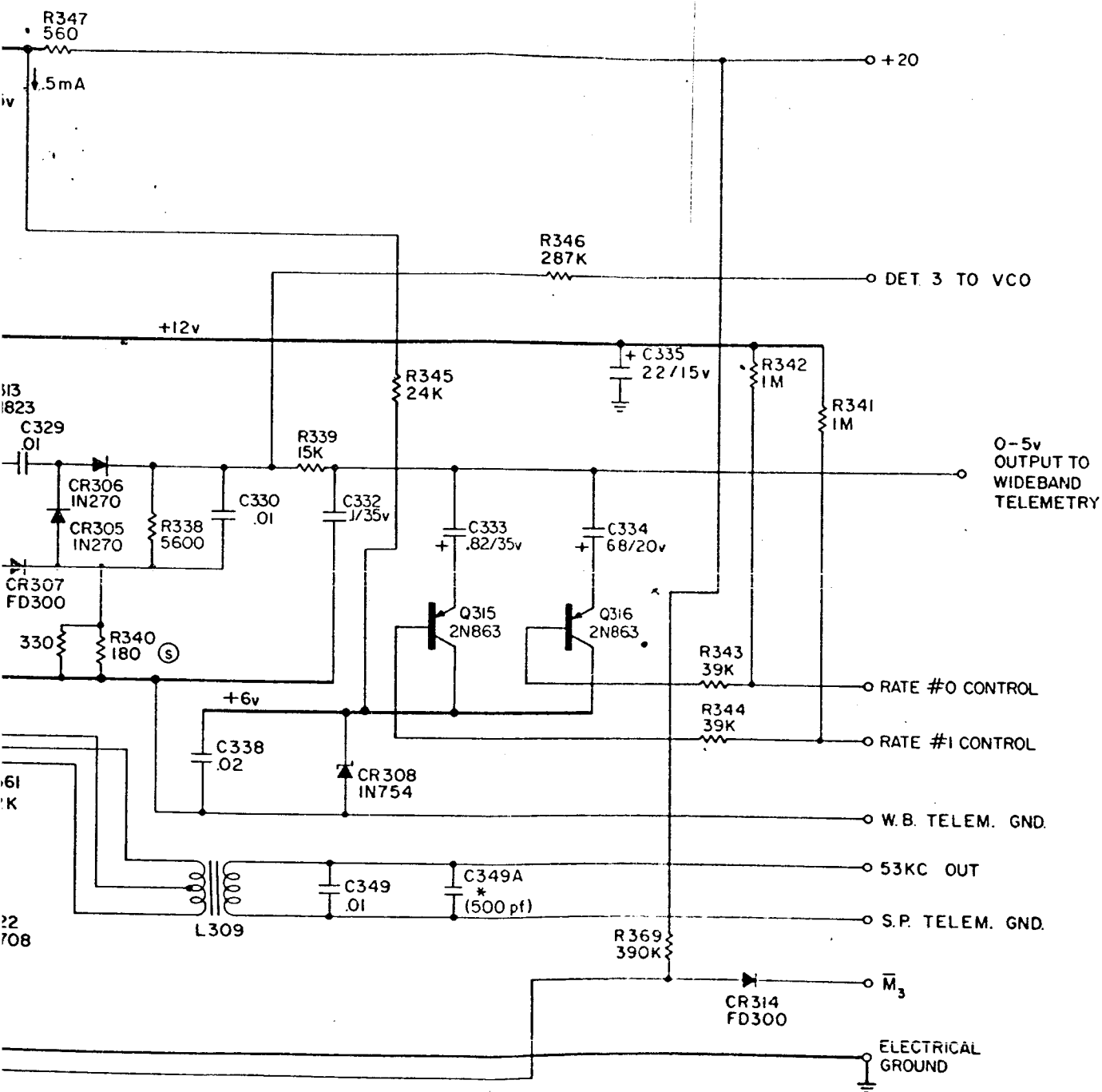
D-4007-35

FIG. A-2 MODULE 2, BAND 2 RECEIVER



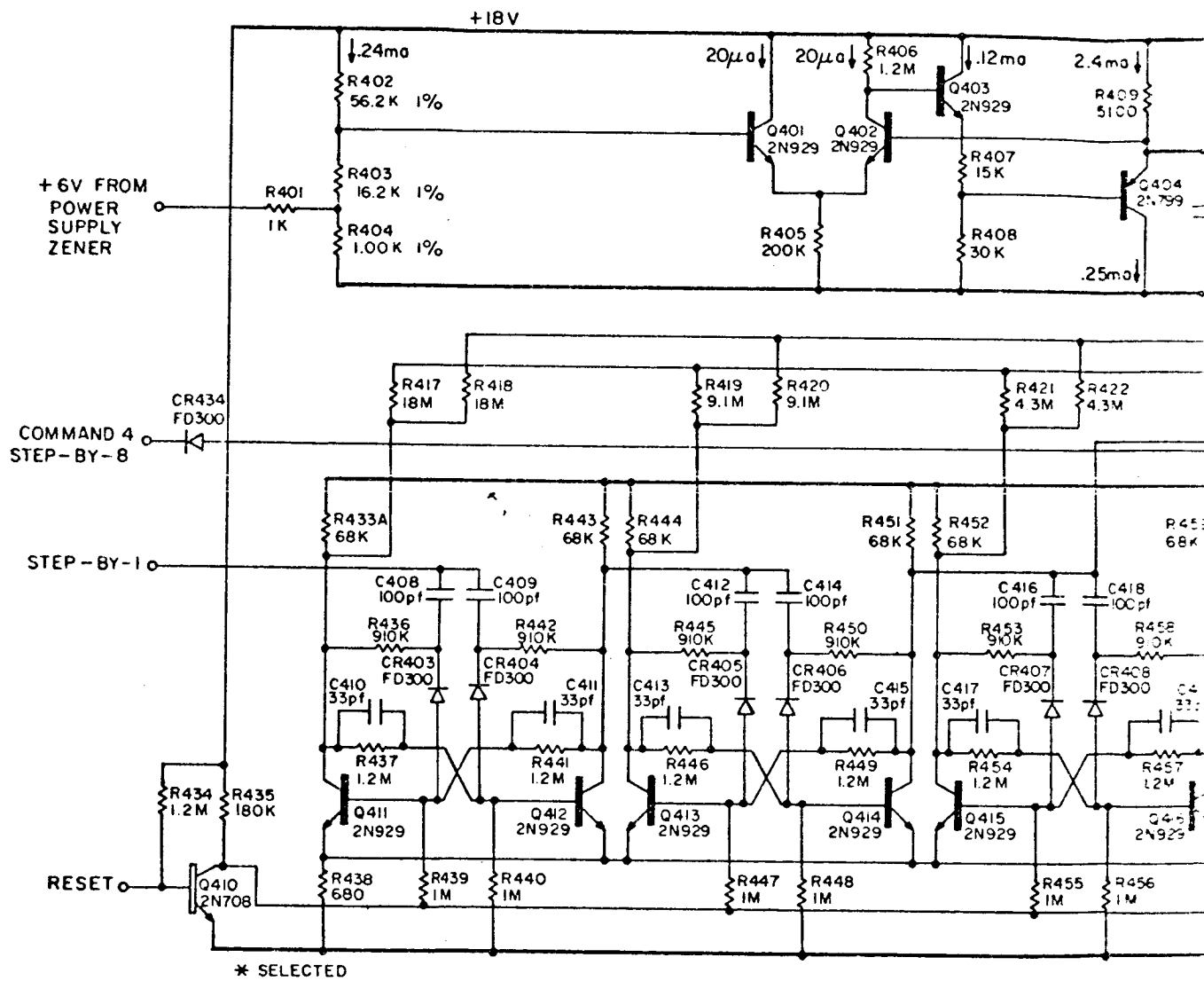


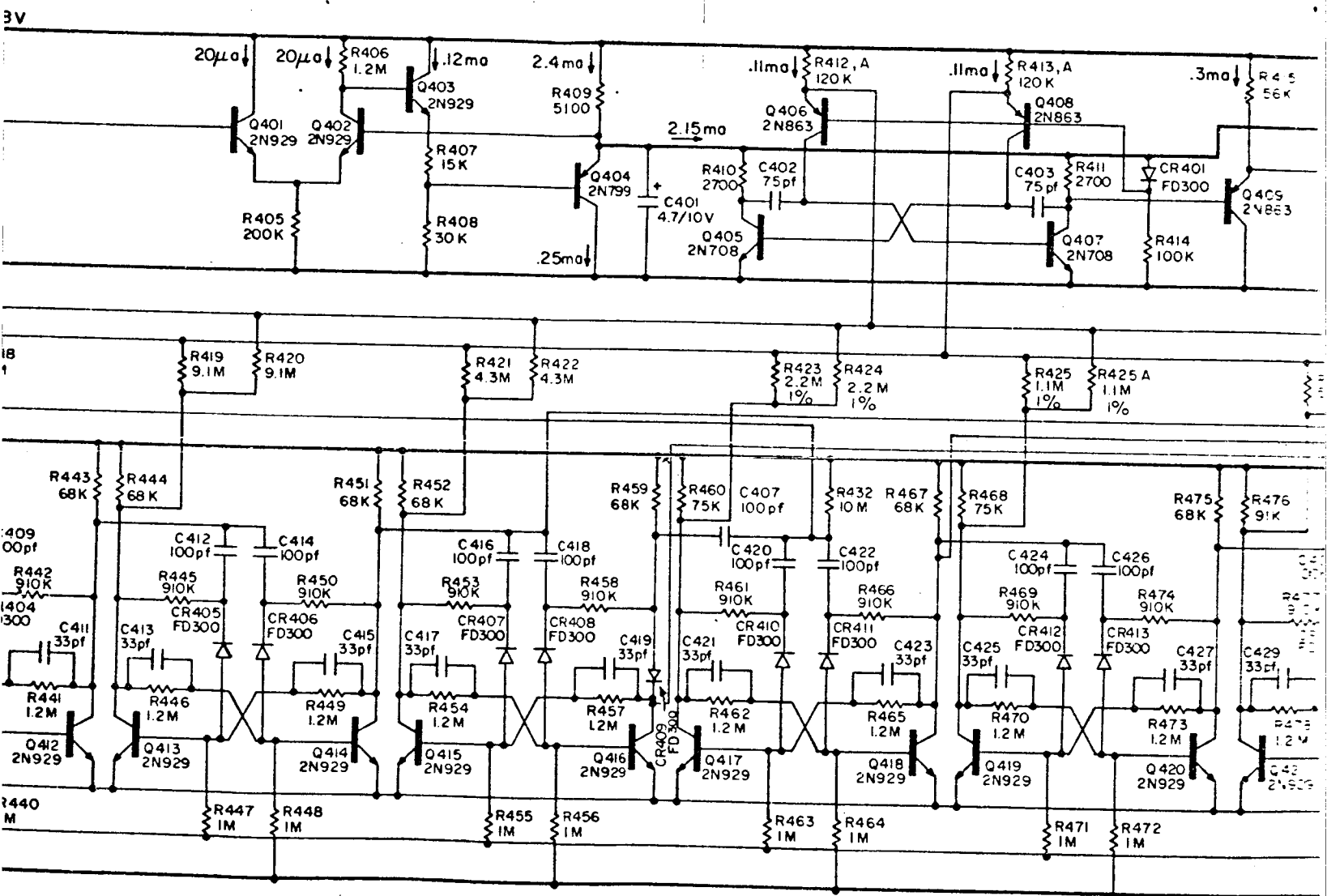


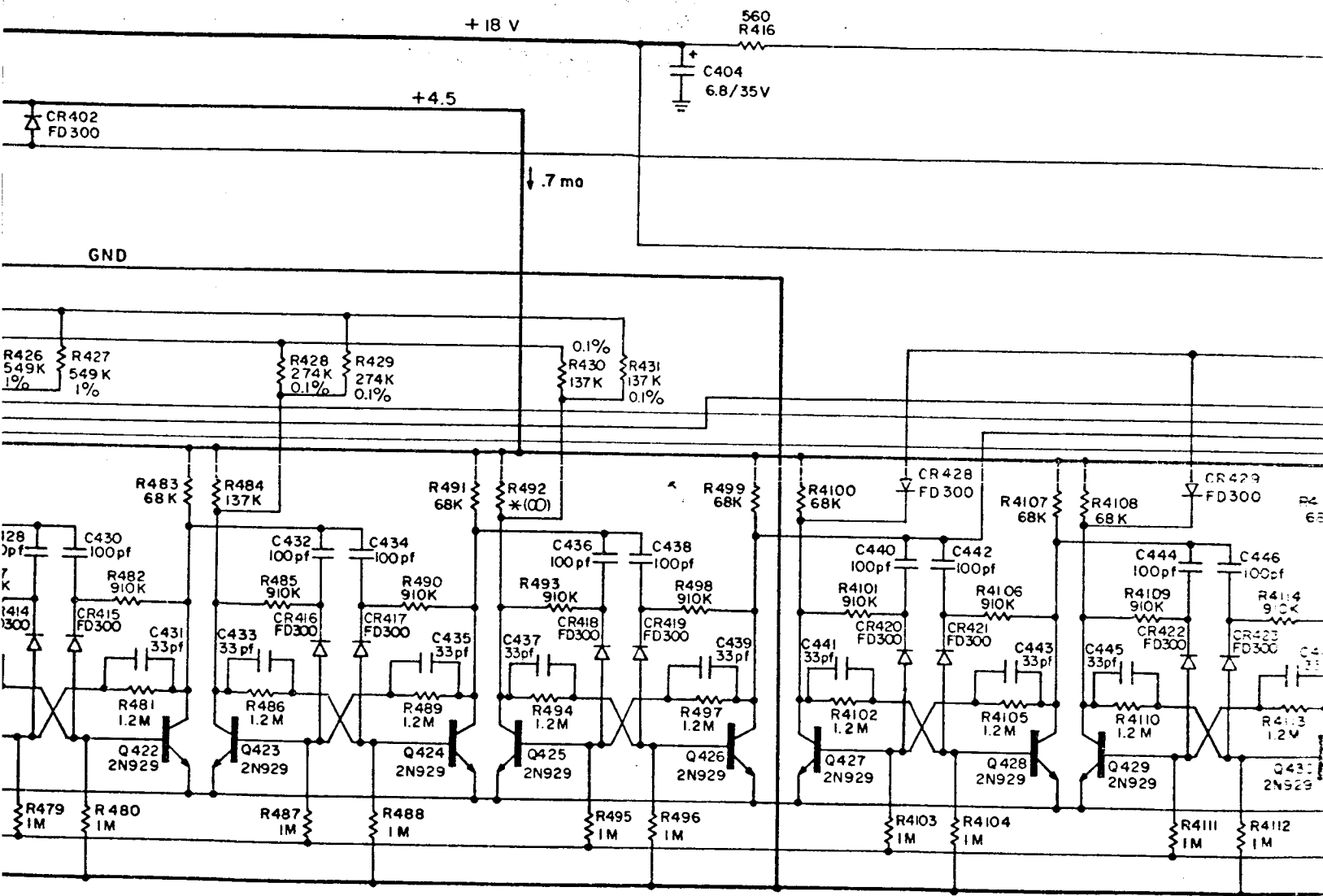


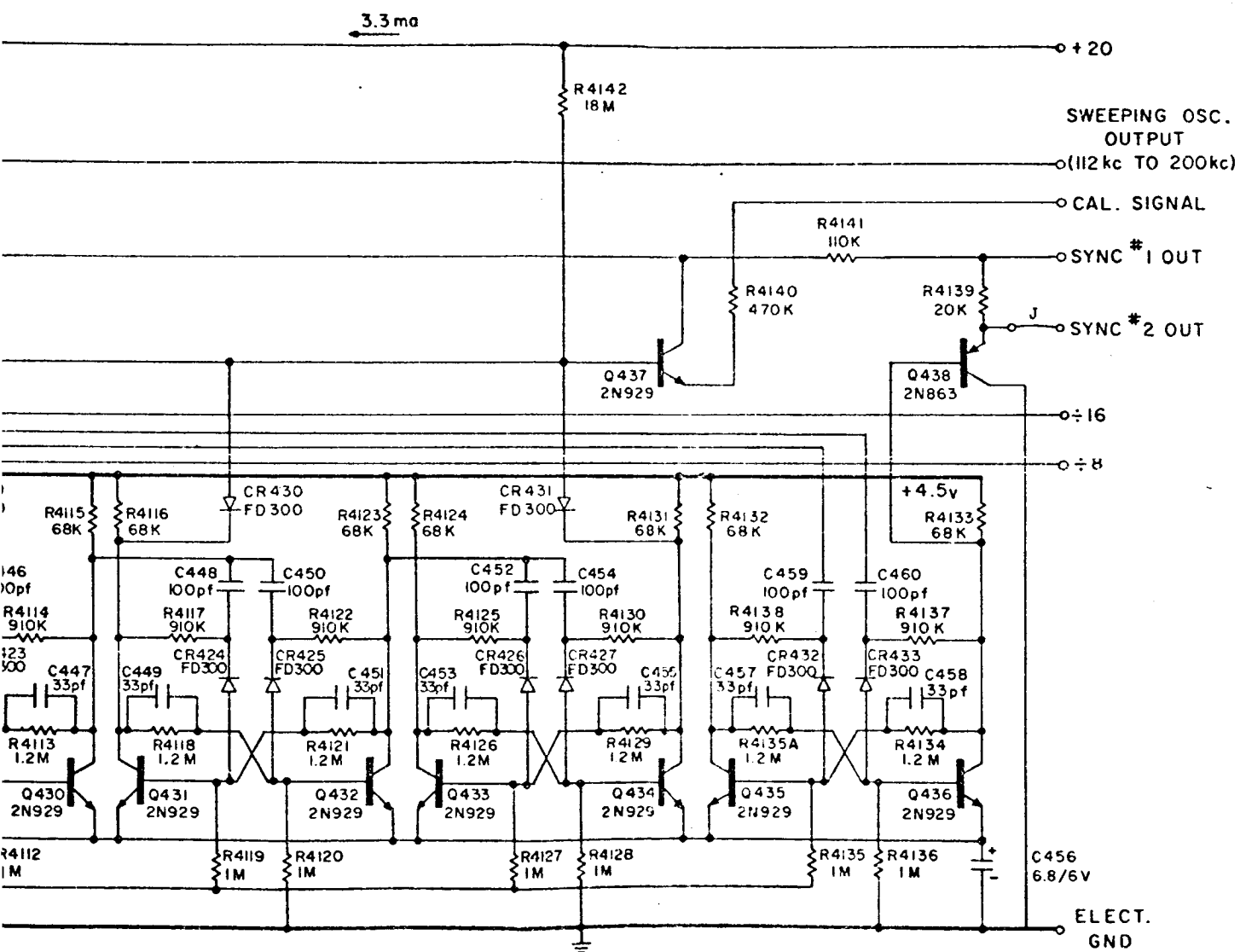
D-4007-36

FIG. A-3 MODULE 3, BAND 3 RECEIVER



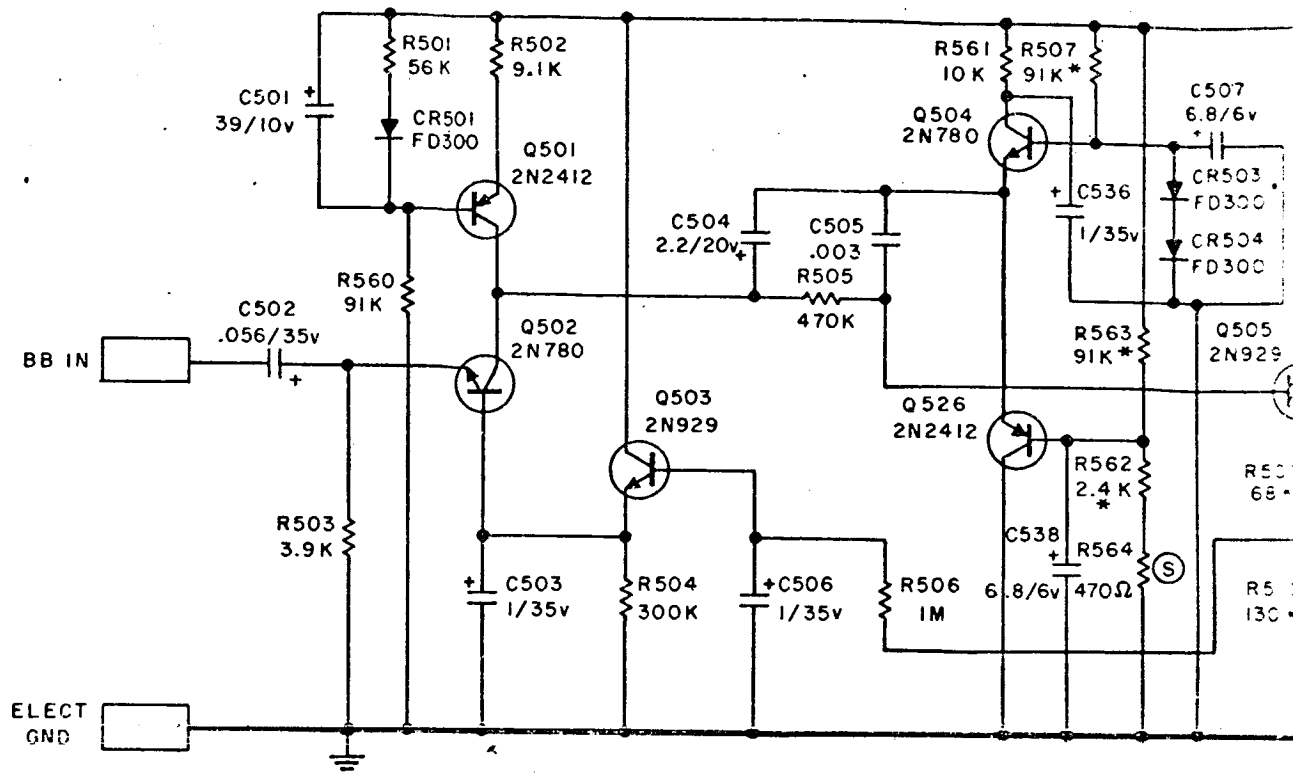


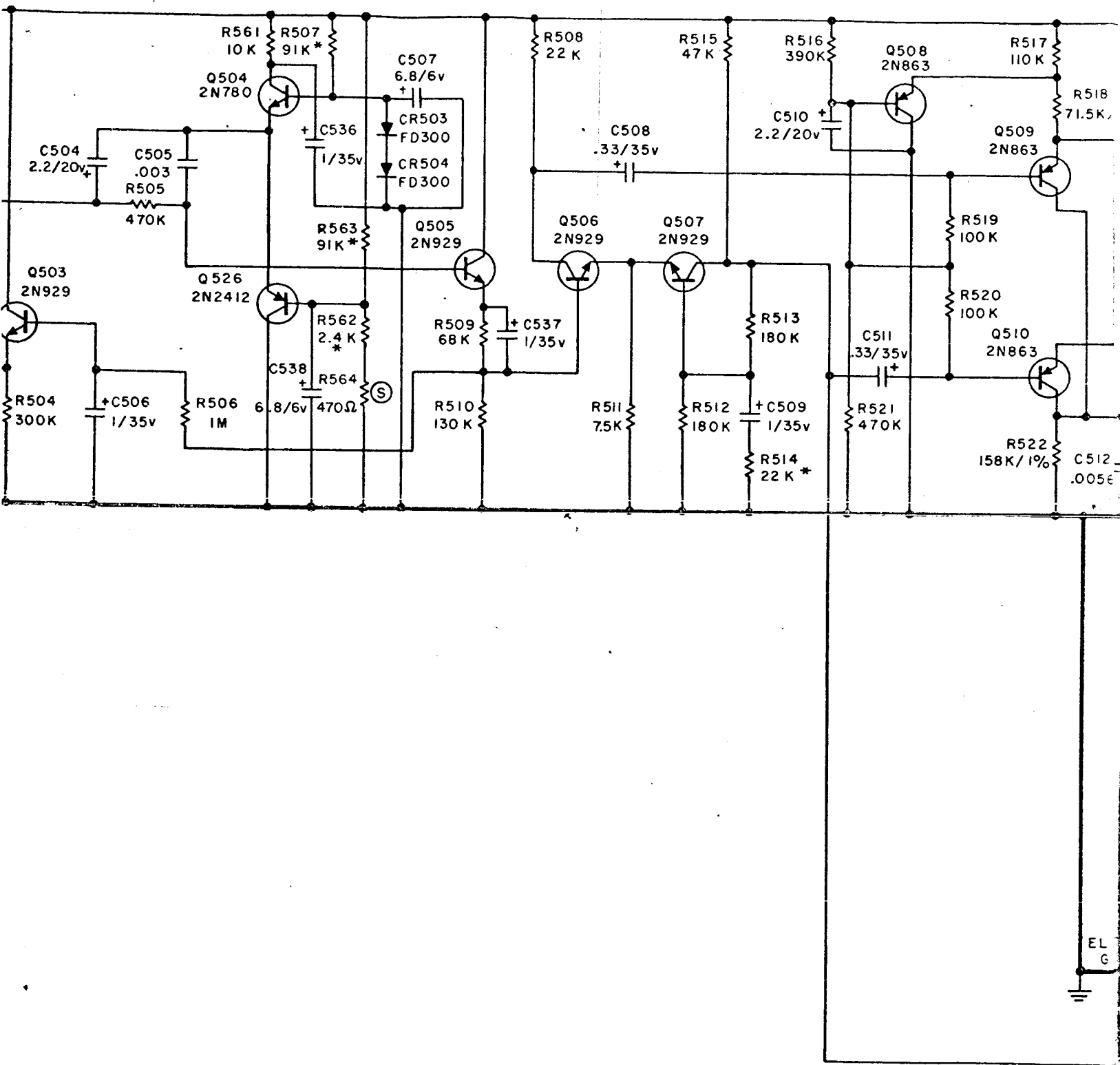


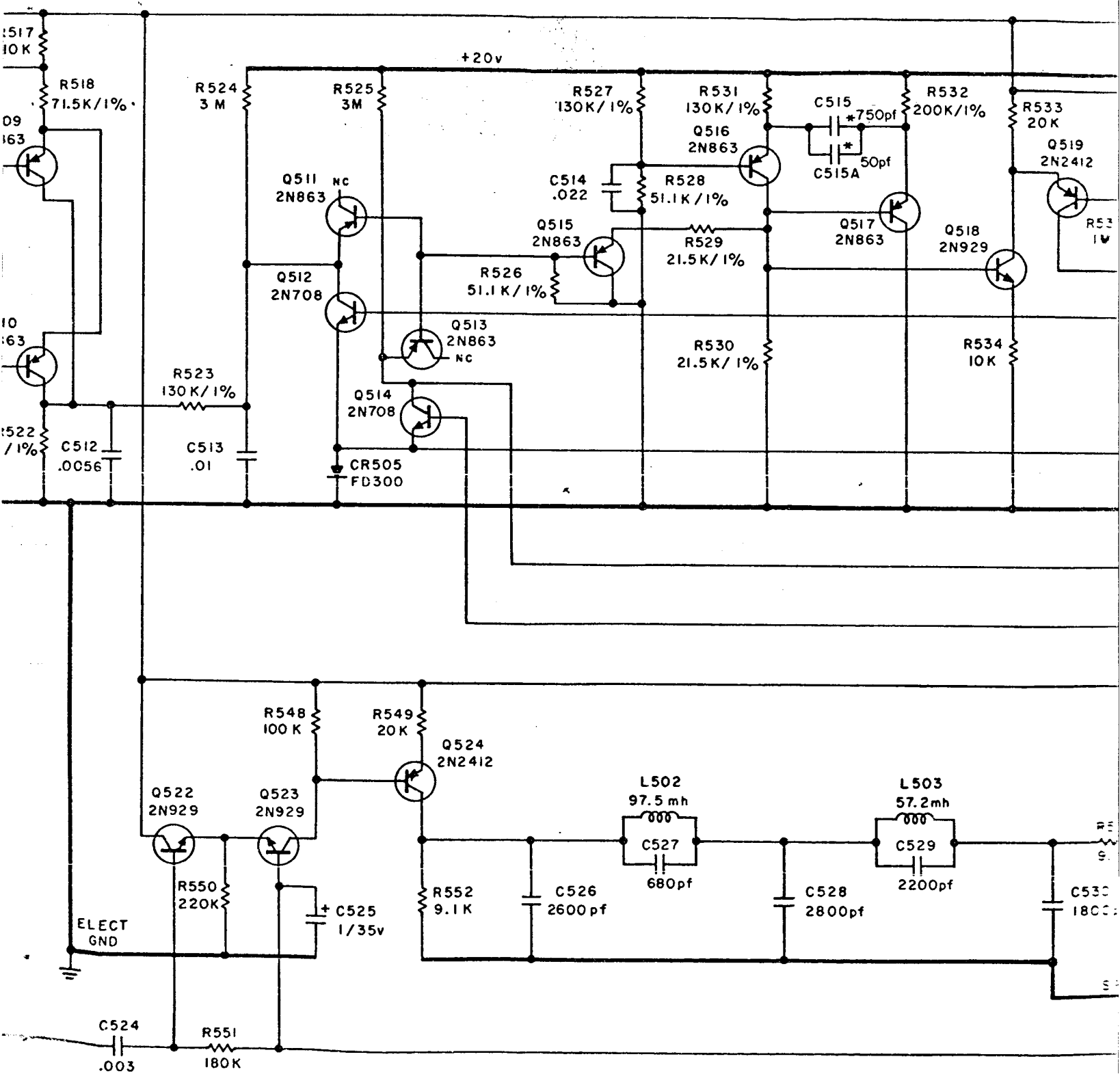


D-4007-37

FIG. A-4 MODULE 4, SWEEP OSCILLATOR AND SCALERS







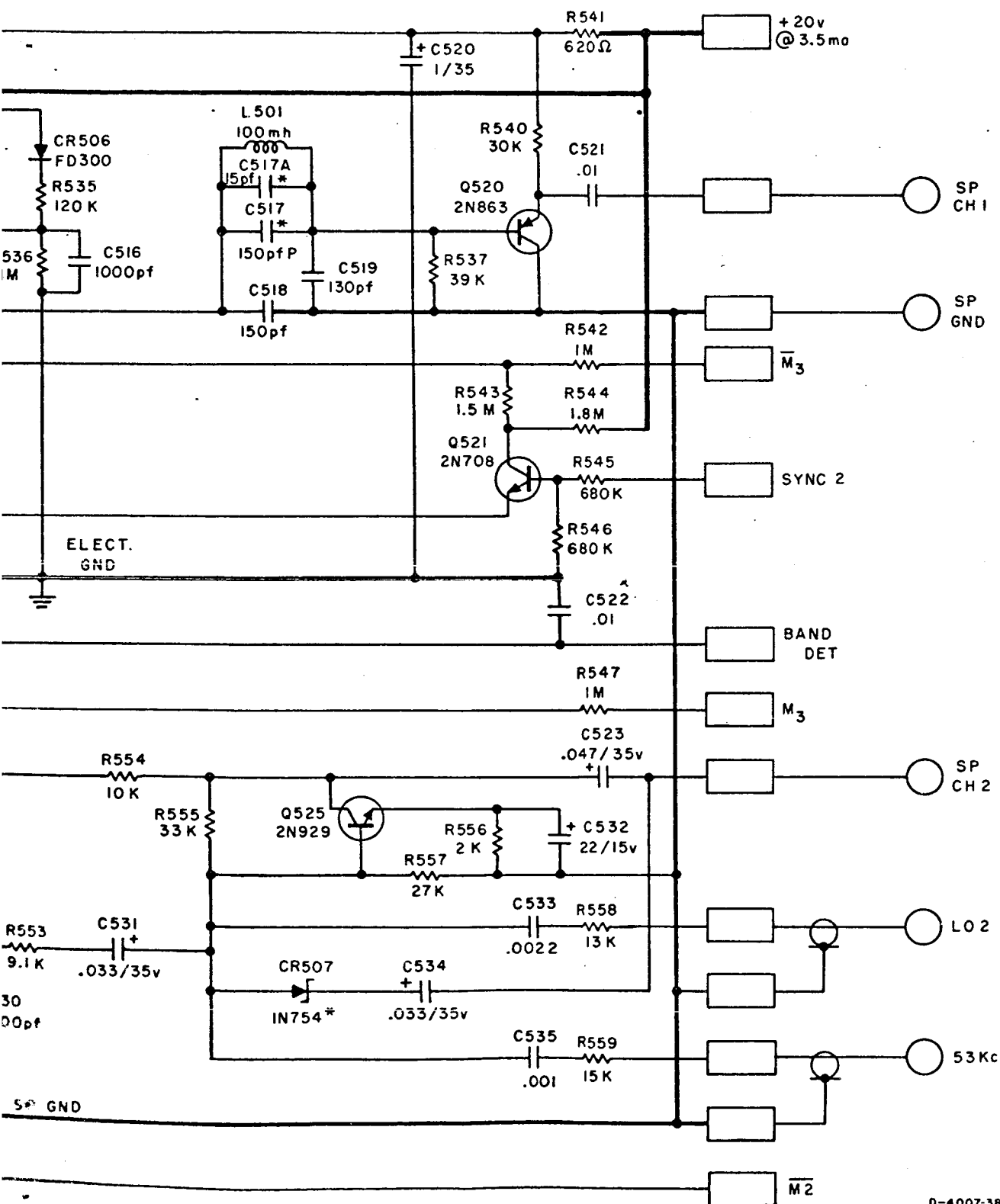
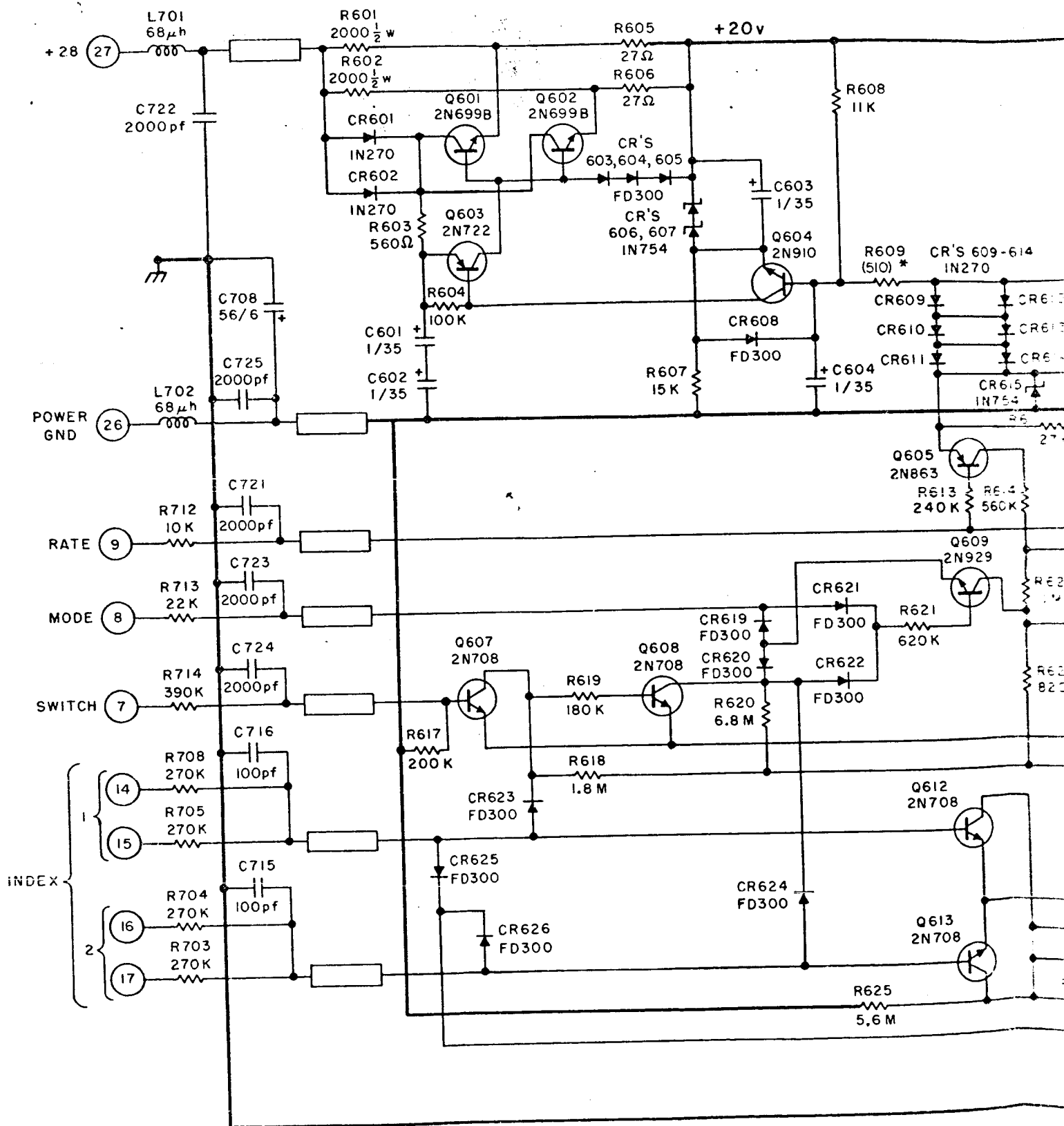
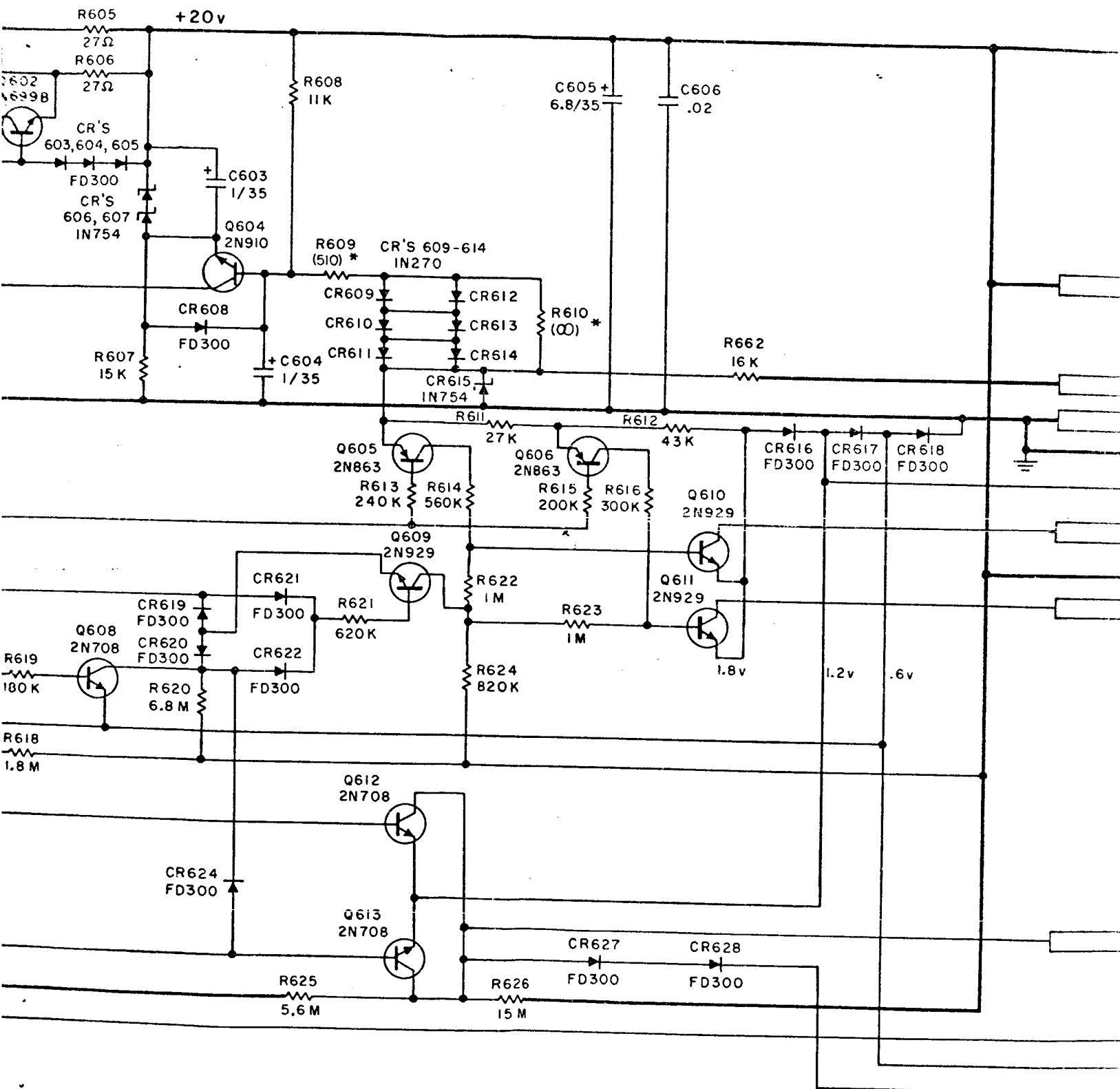
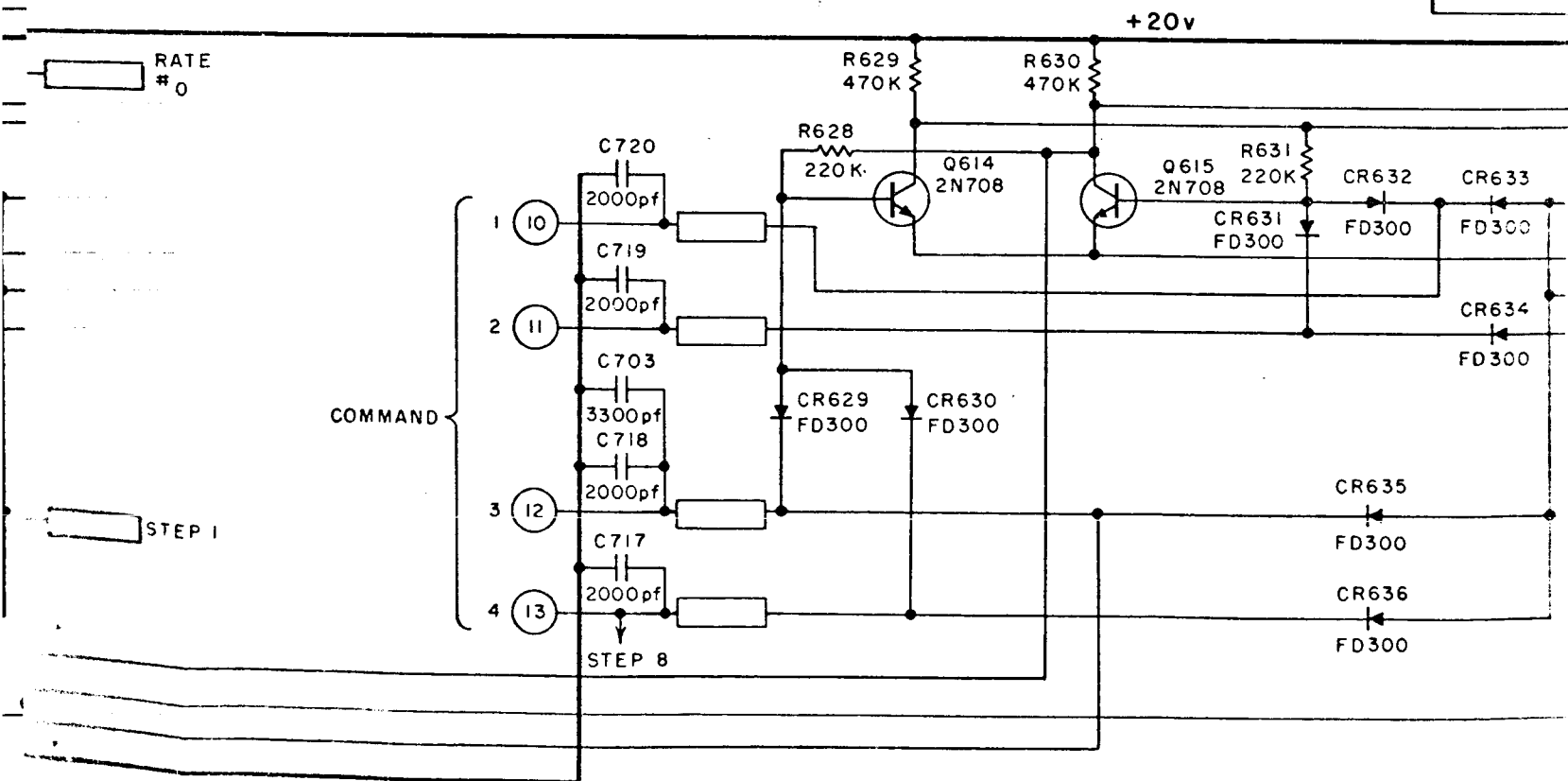
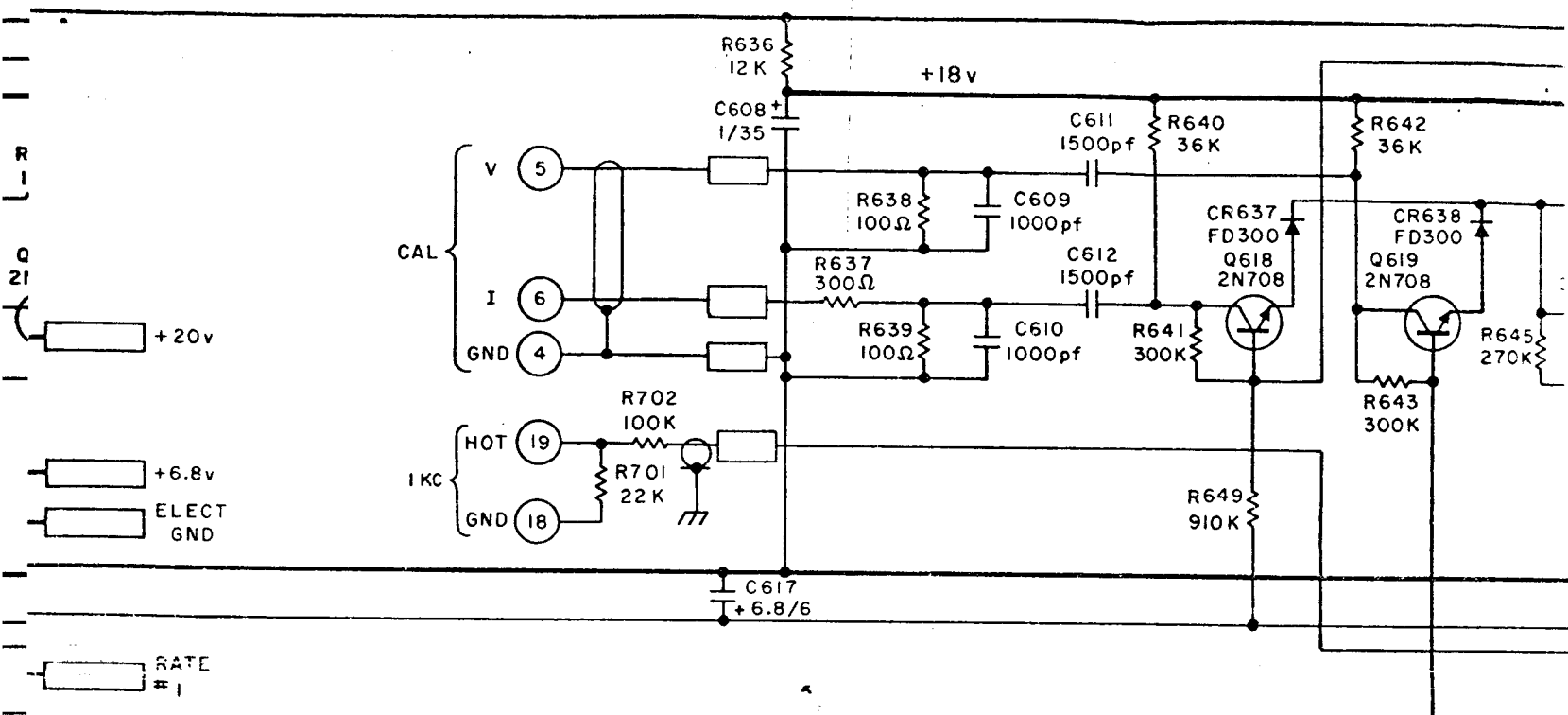


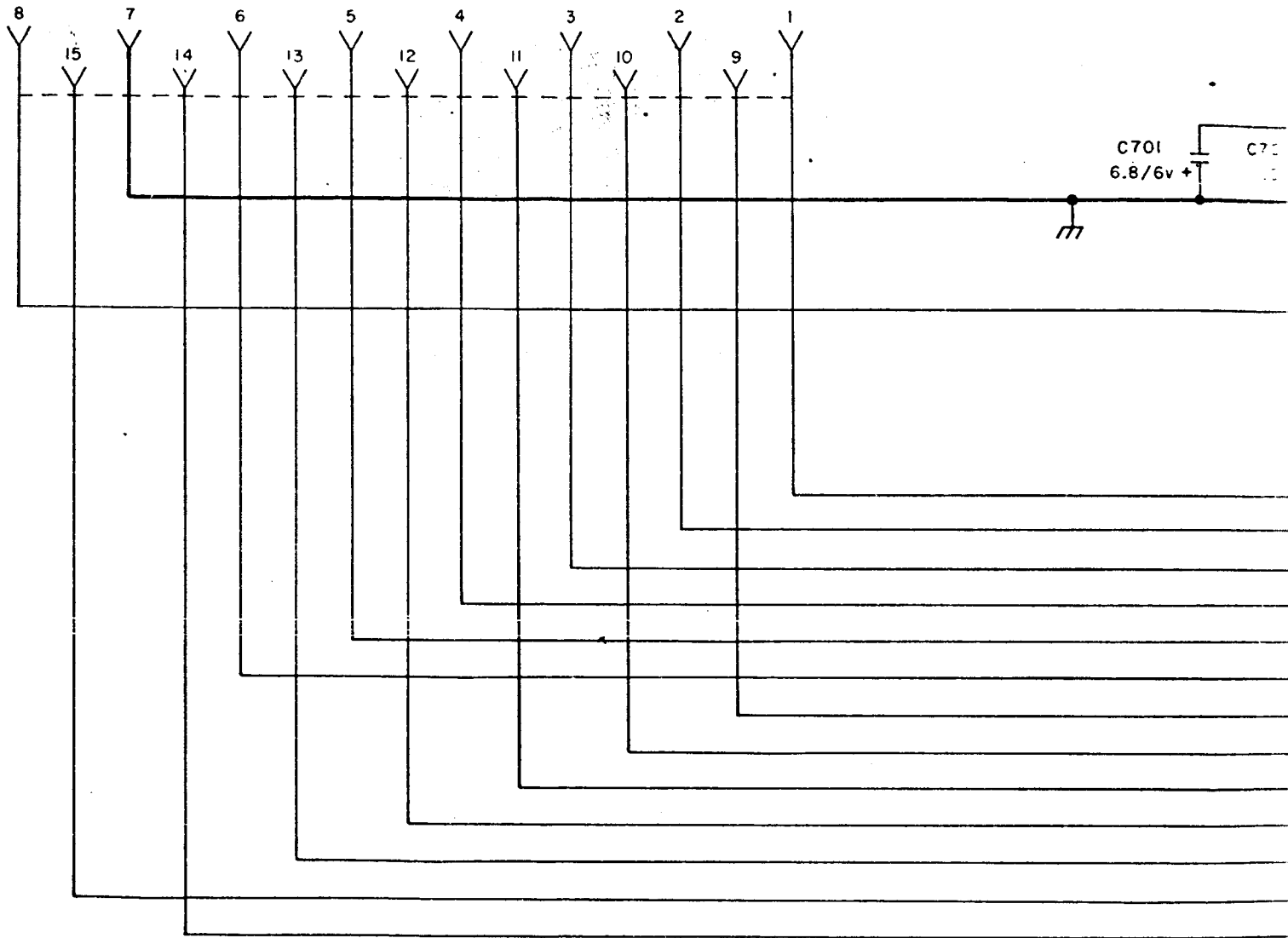
FIG. A-5 MODULE 5, BROADBAND RECEIVER AND VCO





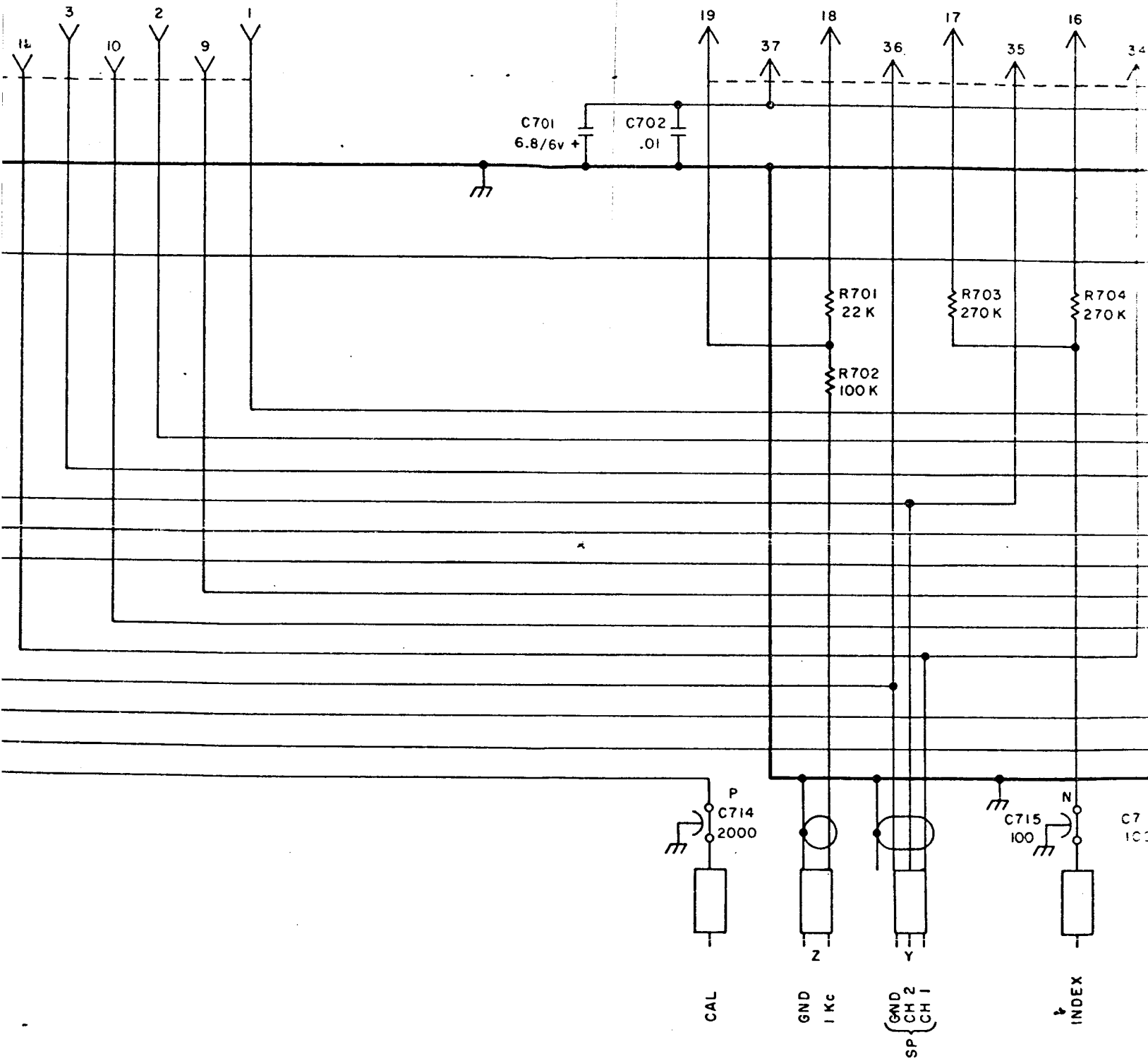


TEST CONNECTOR

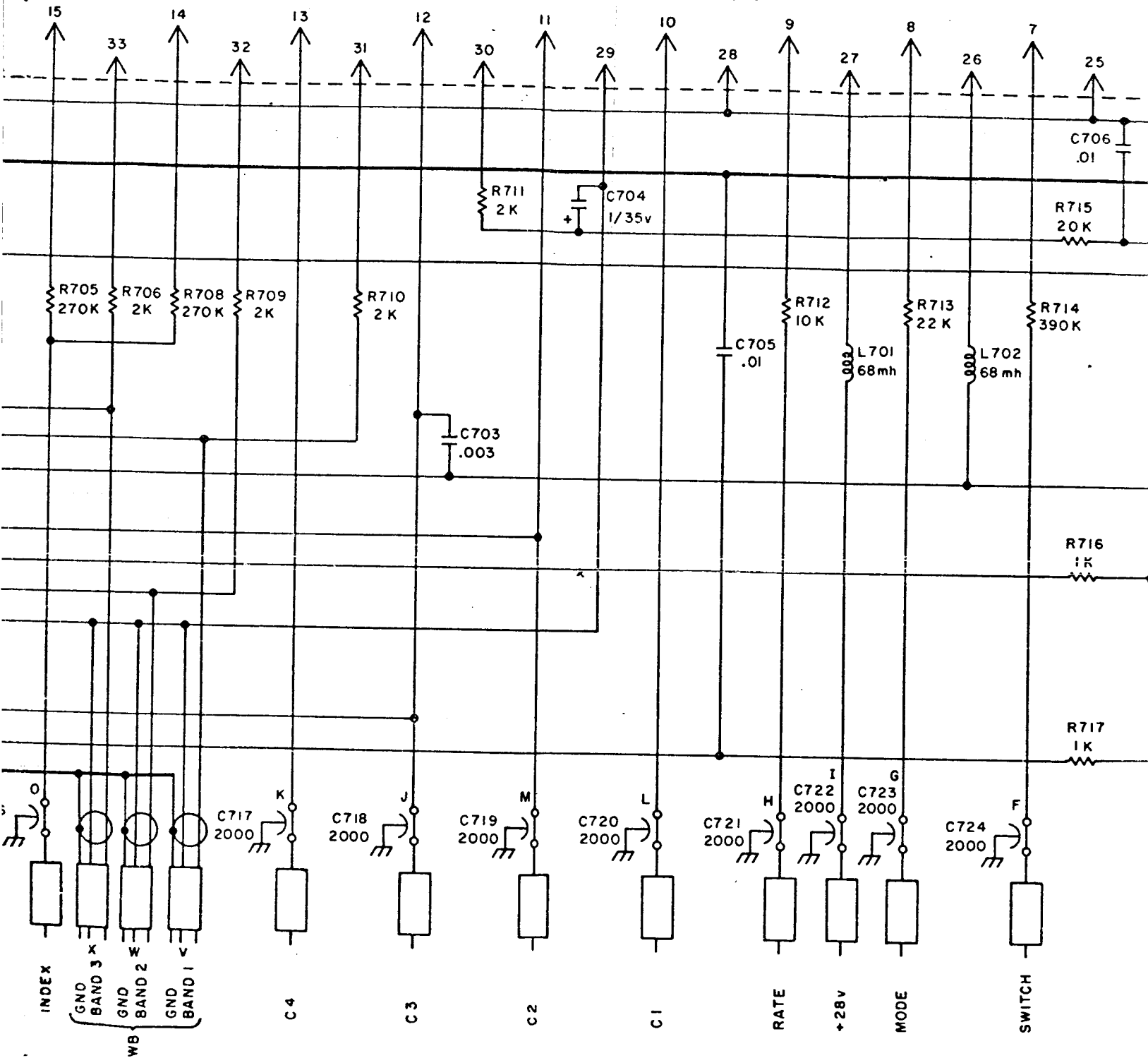


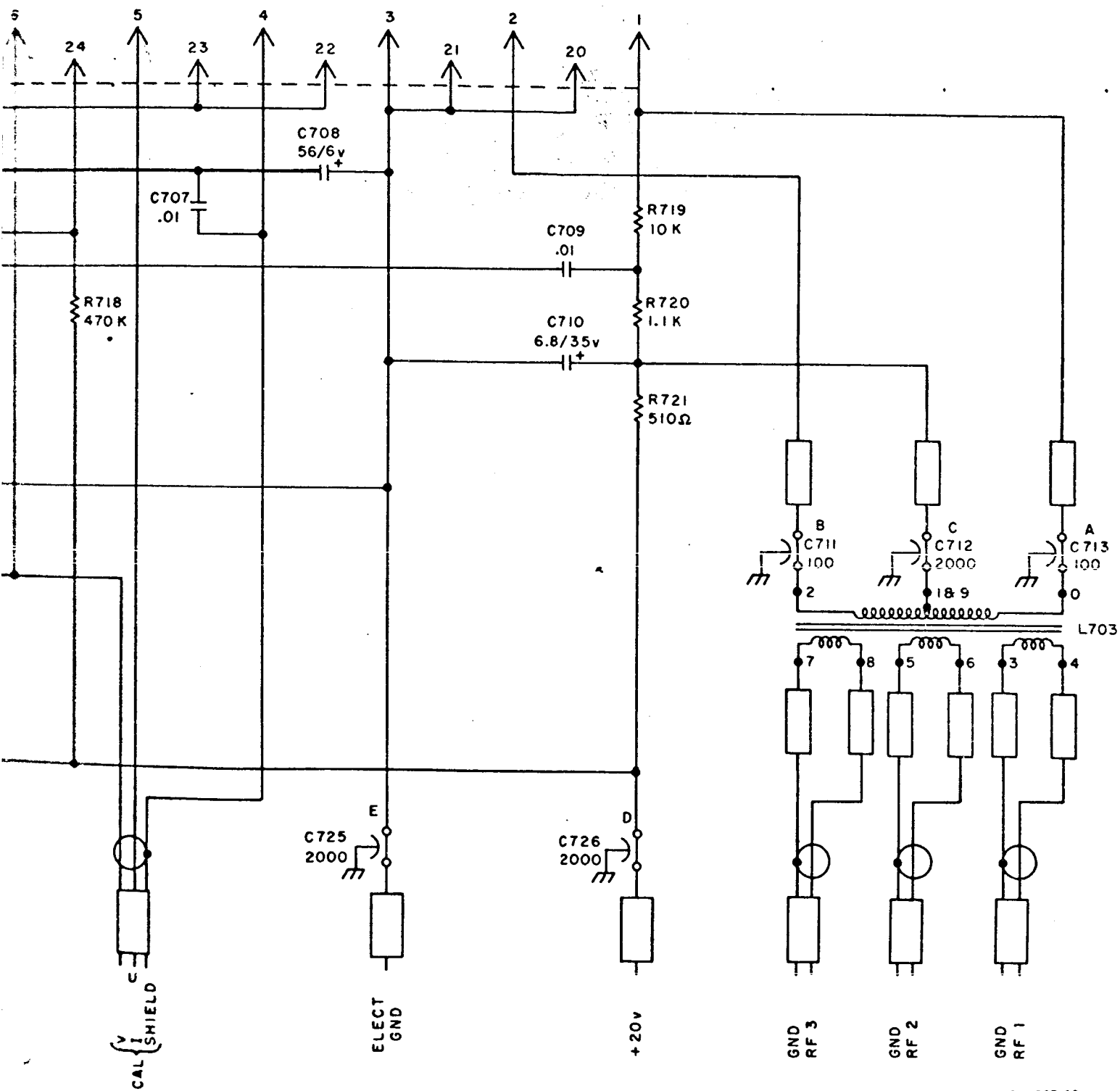
C701
6.8/6v +

C702



INTERFACE CONNECTOR





D-4007-40

FIG. A-7 MODULE 7, INTERFACE DECOUPLING AND DISTRIBUTION TRANSFORMER

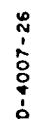
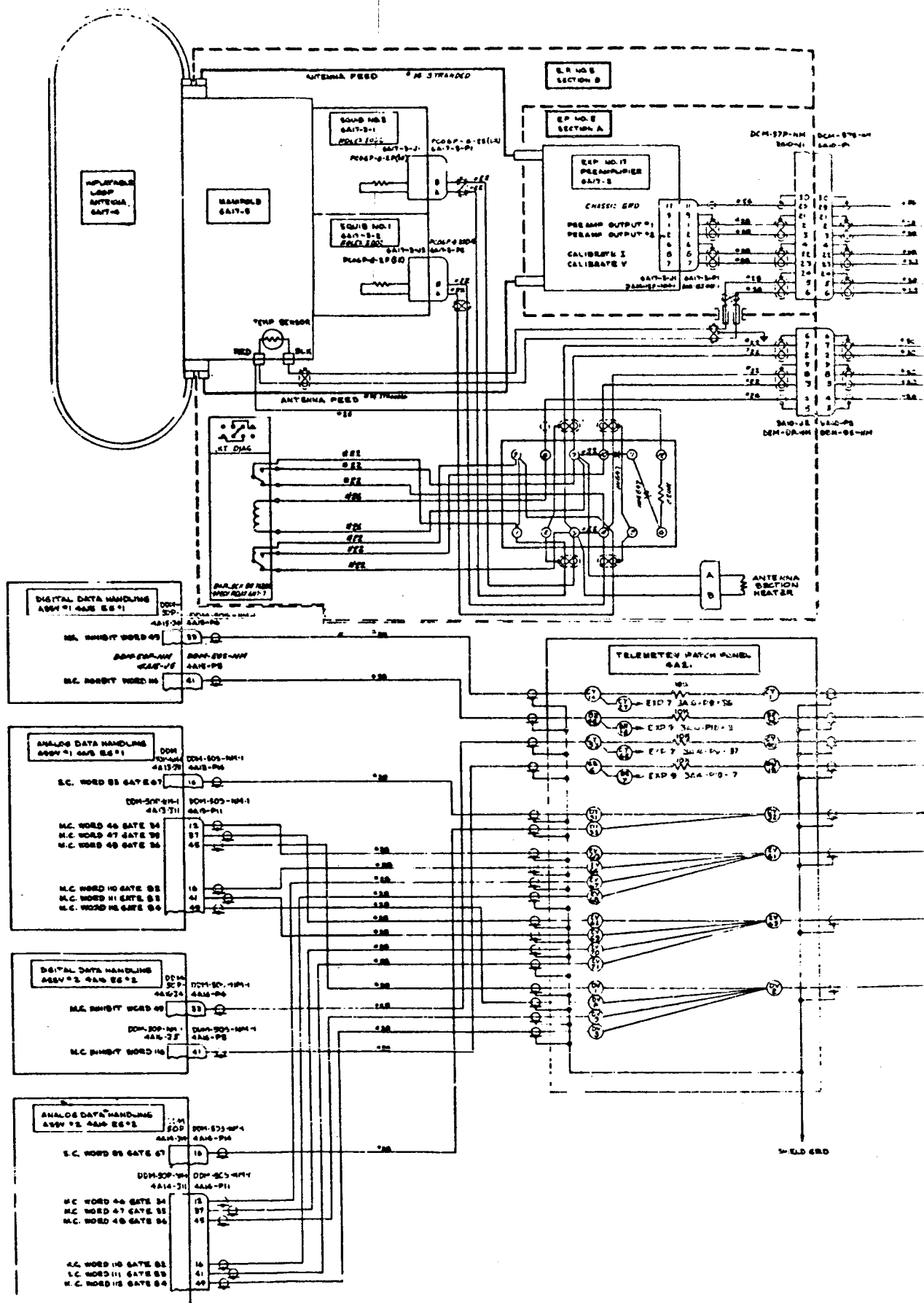
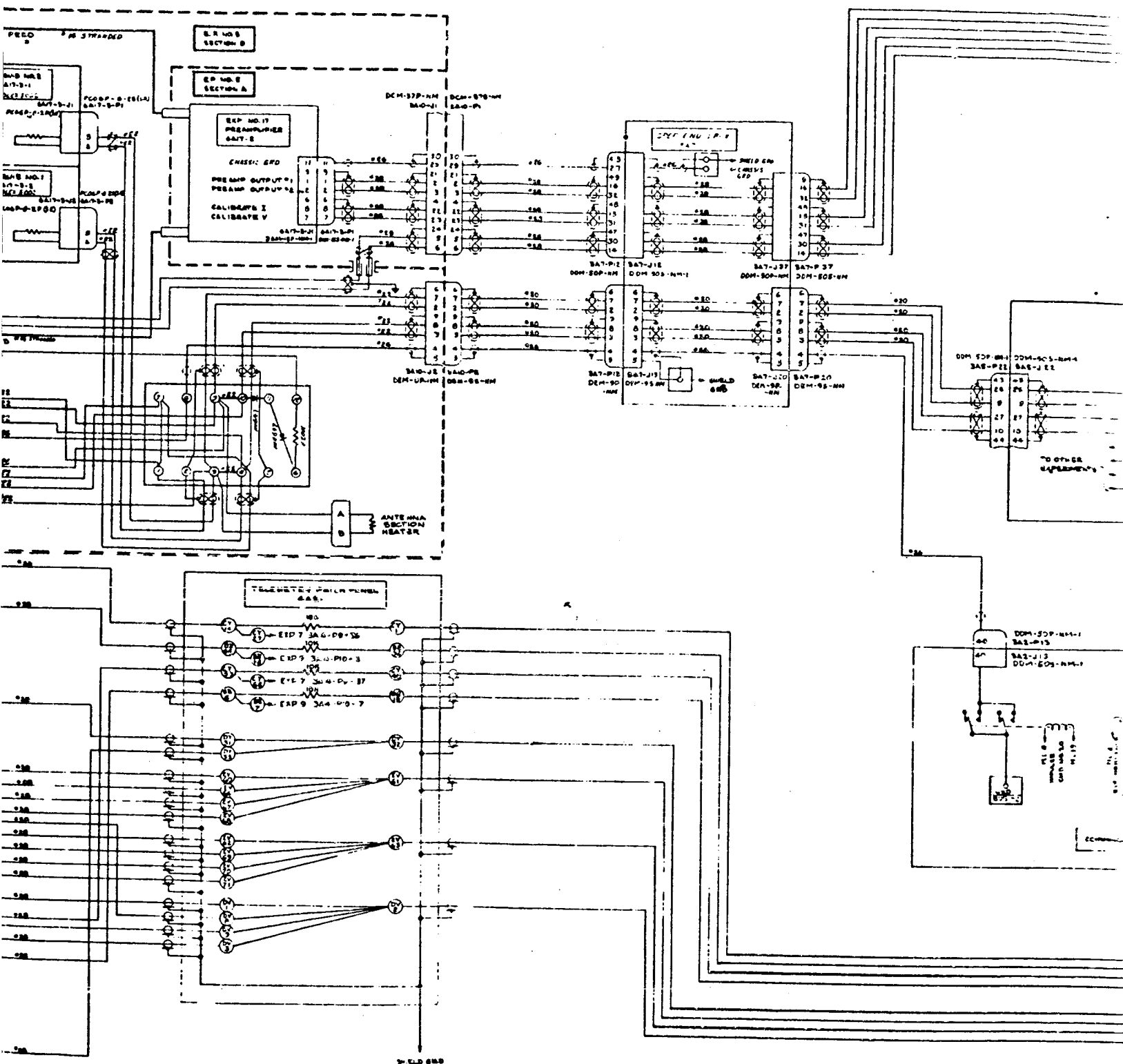
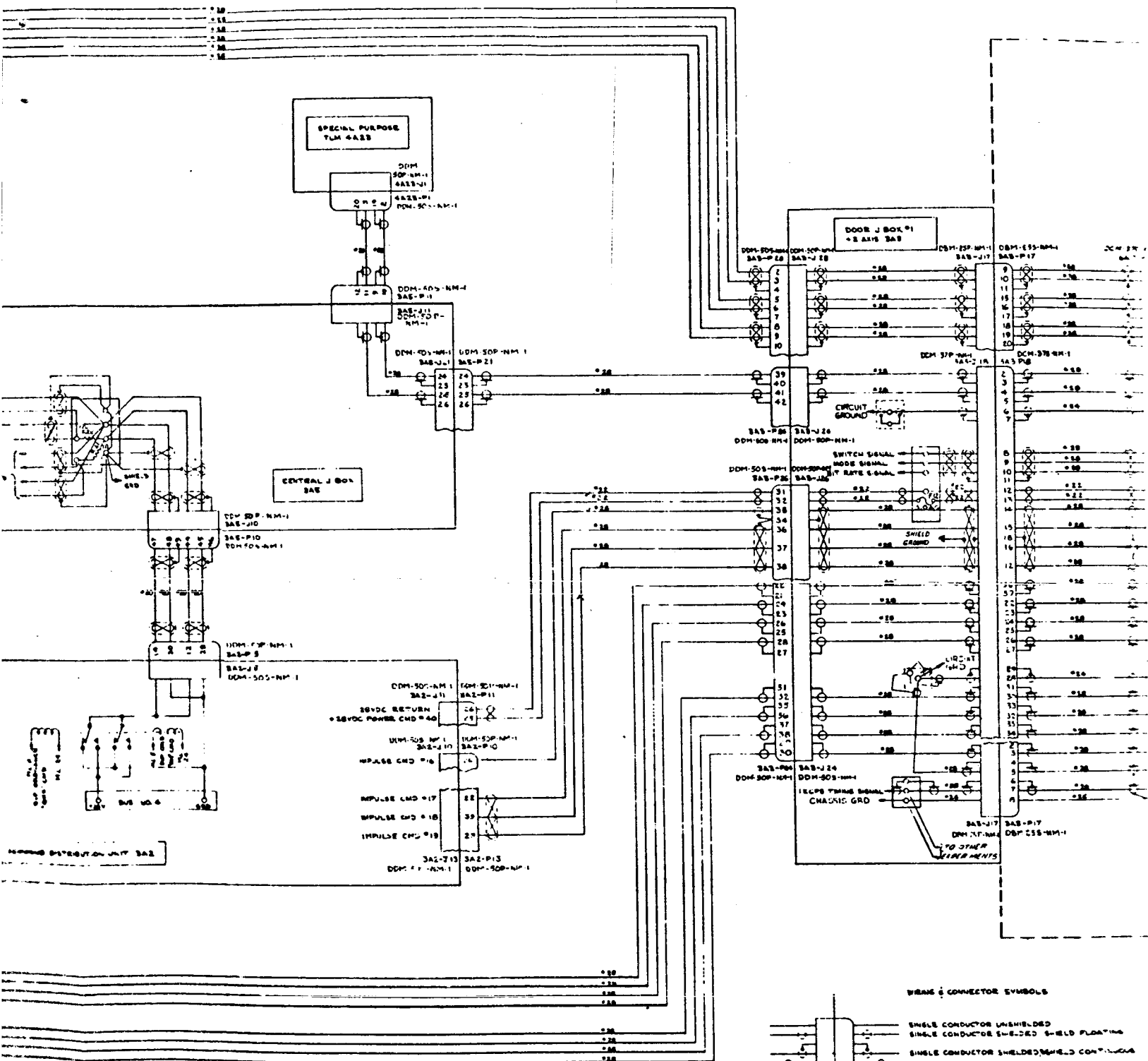


FIG. A-8 PREAMPLIFIER







WIRE & CONNECTOR SYMBOLS

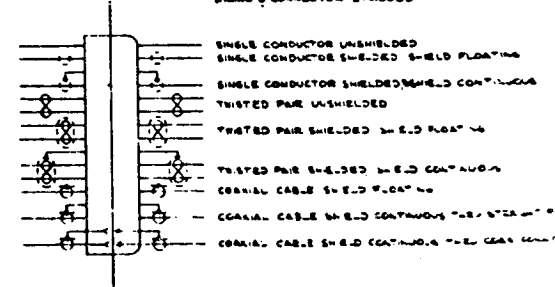


FIG. A-9 WIRING DIAGRAM

Appendix B
EXPERIMENT PARTS LIST

Appendix B

EXPERIMENT PARTS LIST

- Notes:
- (1) All resistors are carbon composition, 1/4 watt, 5%, unless otherwise specified.
 - (2) All tantalum capacitors are Sprague Type 150D.
 - (3) For inductor specification see Table B-1.
 - (4) All semiconductors were tested and logged.
 - (5) Components are listed separately for each module.
 - (6) Unless otherwise indicated, resistors are in ohms, integral capacitor values are in picofarads (except tantalum) and fractional capacitor values are in microfarads.
 - (7) All polystyrene capacitors are Siemens 2.5%, 125 volt.
 - (8) All ceramic feed-through capacitors are $\pm 20\%$ Centralab type DA-784.

Table B-I
PARTS LIST, MODULE 1

Ref. No.	Value	Specification	Ref. No.	Value	Specification
C101	.22/35v	Tantalum	C156	39/10V	Tantalum
C102	.015	Ceramic, Glenco Min-M-.015K	C157	6.8/35V	Tantalum
C103	500	Poly.	C158	22/15V	Tantalum
C104	.022	Ceramic, Glenco Min-M-.022K	C159	.02	Ceramic, Glenco Min-V .02Z
C105	2000	Poly.	CR101	FD300	
C106	.022	Ceramic, Glenco Min-M-.022K	CR102	FD300	
C107	750	Poly.	CR103	FD300	
C108	.015	Ceramic, Glenco Min-M-.015K	CR104	FD300	
C109	.02	Ceramic, Glenco Min-V-.02Z	CR105	FD300	
C110	.01	Ceramic, Glenco Min-V-.01Z	CR106	FD300	
C111	33	Ceramic, Aerovox Cerafil	CR107	FD300	
C112	100		CR108	FD300	
C113	100		CR109	FD300	
C114	33		CR110	IN754	
C115	33		CR111	IN270	
C116	100		CR112	IN270	
C117	100		CR113	IN270	
C118	33		CR114	IN754	
C119	33		Q101	2N863	
C120	100		Q102	2N708	
C121	100		Q103	2N708	
C122	33		Q104	2N708	
C123	6.8/6V	Tantalum	Q105	2N708	
C124	39/10V	Tantalum	Q106	2N708	
C125	680	Poly.	Q107	2N708	
C126	2.2/20V	Tantalum	Q108	2N708	
C127	680	Poly.	Q109	2N708	
C128	33	Poly.	Q110	2N708	
C129	1/35V	Tantalum	Q111	2N708	
C130	680	Poly.	Q112	2N708	
C131	680	Poly.	Q113	2N929	
C132	1/35V	Tantalum	Q114	2N929	
C133	680	Poly.	Q115	2N929	
C134	.01	Ceramic, Glenco Min-V-.01Z	Q116	2N929	
C135	2.2/20V	Tantalum	Q117	2N863	
C136	390	Poly., Selected, Typical value shown	Q118	2N823	
C137	1/35V	Tantalum	Q119	2N823	
C138	1/35V	Tantalum	Q120	2N799	
C139	2.2/20V	Tantalum	Q121	2N863	
C140	1000	Ceramic, Aerovox Cerafil	Q122	2N863	
C141	Not used		Q123	2N863	
C142			R101	9100	
C143			R102	8200	
C144			R103	2400	
C145			R104	4300	
C146			R105	24K	
C147			R106	240K	
C148			R107	30K	
C149			R108	15K	
C150	4.7/10V	Tantalum	R109	150K	
C151	.01	Ceramic, Glenco Min-V-.01Z	R110	150K	
C152	.33/35V	Tantalum	R111	1.0M	
C153	.33/35V	Tantalum	R112	150K	
C154	.68/35V	Tantalum	R113	150K	
C155	4.7/10V	Tantalum	R114	1.0M	
			R115	15K	

Table B-I (Continued)

Ref. No.	Value	Specification	Ref. No.	Value	Specification
R116	15K				
R117	150K				
R118	150K				
R119	1.0M				
R120	15K				
R121	150K				
R122	150K				
R123	1.0M				
R124	15K				
R125	150K				
R126	150K				
R127	1.0M				
R128	150K				
R129	15K				
R130	150K				
R131	1.0M				
R132	3000				
R133	33K				
R134	47K				
R135	3000				
R136	3000				
R137	33K				
R138	47K				
R139	20K				
R140	3000				
R141	3000				
R142	20K				
R143	47K				
R144	62K				
R145	2700				
R146	390				
R147	2700				
R148	62K				
R149	47K				
R150	27K				
R151	5600	Sensistor, 1/8 w, 10%			
R152	56K	Selected, Typical value shown			
R153	680K				
R154A	180K				
R154	110K				
R155	68K				
R156	10K				
R157	6200				
R158	10K				
R159	51K				
R160	24K				
R161	180	Sensistor, 1/8 w, 10%			
R162	5600				
R163	15K				
R164	Not used				
R165	Not used				
R166	39K				
R167	39K				
R168	560				
R169	3000	Selected, Typical value shown			

Table B-II
PARTS LIST, MODULE 2

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
C201	.068/35	Tantalum	C246	15/20V	Tantalum
C202	.003	Ceramic, Glenco, Min-M .003K	C247	39/10V	Tantalum
C203	110 PF	Poly.	C248	22/15V	Tantalum
C204	.0056	Ceramic, Glenco, Min-M .0056K	C249	6.8/35V	Tantalum
C205	430 PF	Poly.	C250	.02	Ceramic, Glenco, Min-V-.02Z
C206	.0056	Ceramic, Glenco, Min-M .0056K	CR200	FD300	
C207	170 PF	Poly.	CR201	FD300	
C208	.003	Ceramic, Glenco, Min-M .003K	CR202	FD300	
C209A	.01	Ceramic, Glenco, Min-V .01Z	CR203	FD300	
C209B	.01	Ceramic, Glenco, Min-V .01Z	CR204	FD300	
C210A	820 PF	Poly.	CR205	FD300	
C210B	200 PF	Poly.	CR206	FD300	
C210C	1000 PF	Poly.	CR207	IN754	
C210D	680 PF	Poly.	CR208	FD300	
C210E	620 PF	Poly.	CR209	FD300	
C210	.01	Ceramic, Glenco, Min-V .01Z	CR210	FD300	
C211	33 PF	Ceramic, Aerovox Cerafil	CR211	IN270	
C212	100 PF		CR212	IN270	
C213	100 PF		CR213	IN270	
C214	33 PF		CR214	IN754	
C215	33 PF		Q200A	2N863	
C216	100 PF		Q200	2N910	
C217	100 PF		Q201	2N863	
C218	33 PF		Q202	2N708	
C219	33 PF		Q203	2N708	
C220	100 PF		Q204	2N708	
C221	100 PF		Q205	2N708	
C222	33 PF		Q206	2N708	
C223	6.8/6V	Tantalum	Q207	2N708	
C224	2.2/20V	Tantalum	Q208	2N708	
C225	390 PF	Poly.	Q209	2N708	
C226	2.2 PF	Poly.	Q210	2N708	
C227	390 PF	Poly.	Q211	2N708	
C228	1/35V	Tantalum	Q212	2N708	
C229	1/35V	Tantalum	Q213	2N929	
C230	390 PF	Poly.	Q214	2N929	
C231	2.2 PF	Poly.	Q215	2N929	
C232	390 PF	Poly.	Q216	2N929	
C233	.001	Ceramic, Aerovox Cerafil	Q217	2N863	
C234	4.7/10V	Tantalum	Q218	2N823	
C235	8	Poly., Selected, Typical value shown	Q219	2N823	
C236	1/35V	Tantalum	Q220	2N799	
C237	.01	Ceramic, Glenco, Min-V-.01Z	Q221	2N863	
C238	2.2/20V	Tantalum	Q222	2N863	
C239	.001	Ceramic, Aerovox Cerafil	R201	5100	
C240	4.7/10V	Tantalum	R202A	10K	
C241	.001		R202B	10K	
C242	.1/35V	Tantalum	R203A	3000	
C243	.1/35V	Tantalum	R203B	3000	
C244	.22/35V	Tantalum	R204	4300	
C245	2.2/20V	Tantalum	R205A	7500	
			R205B	24K	
			R205C	13K	
			R205	16K	
			R206	240K	
			R207	15K	

Table B-II (Concluded)

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
R208	30K		R265	15K	
R209	150K		R266	Not used	
R210	150K		R267	Not used	
R211	150K		R268	39K	
R212	150K		R269	39K	
R213	1.0M		R270	560	
R214	1.0M		R271	5100	Selected, Typical value shown
R215	15K				
R216	15K		R272	24K	
R217	150K				
R218	150K				
R219	15K				
R220	150K				
R221	150K				
R222	1.0M				
R223	1.0M				
R224	8.2K				
R225	56K				
R226	82K				
R227	560K				
R228	560K				
R229	82K				
R230	56K				
R231	8200				
R232	2000				
R233	33K				
R234	47K				
R235	3000				
R236	1200				
R237	3000				
R238	33K				
R239	47K				
R240	20K				
R241	3000				
R242	620				
R243	3K				
R244	20K				
R245	56K				
R246	47K				
R247	2000				
R248	300				
R249	3900				
R250	39K				
R251	100K				
R252	27K				
R253	5600	Sensistor, 10% 1/8 w			
R254	62K	Selected, Typical value shown			
R255	680K				
R256	110K				
R256A	180K				
R257	68K				
R258	10K				
R259	7500				
R260	10K				
R261	Not used				
R262	51K				
R263	5600				
R264	180	Sensistor, 10%, 1/8 w			

Table B-III
PARTS LIST, MODULE 3

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
C301	.02	Ceramic, Glenco, Min-V-.02Z	CR301	IN754	
C302	.002	Ceramic, Glenco, Min-M-.002K	CR302	FD300	
C303	68 PF	Poly.	CR303	FD300	
C304	.003	Ceramic, Glenco, Min-M-.003K	CR304	FD300	
C305	290 PF	Poly.	CR305	IN270	
C306	.003	Ceramic, Glenco, Min-M-.003K	CR306	IN270	
C307	100 PF	Poly.	CR307	FD300	
C308	.002	Ceramic, Glenco, Min-M-.002K	CR308	IN754	
C309	.001	Ceramic, Aerovox Cerafil	CR309	FD300	
C310	4.7-10V	Tantalum	CR310	FD300	
C311	.001	Ceramic, Aerovox Cerafil	CR311	FD300	
C312	2.2/20V	Tantalum	CR312	FD300	
C313	390 PF	Poly.	CR313	FD300	
C314	1 PF	Poly.	CR314	FD300	
C315	390 PF	Poly.	CR315	IN754	
C316	1/35V	Tantalum	Q301	2N863	
C317	1/35V	Tantalum	Q302	2N708	
C318	390 PF	Poly.	Q303	2N708	
C319	1 PF	Poly.	Q304	2N708	
C320	390 PF	Poly.	Q305	2N708	
C321	.001	Ceramic, Aerovox Cerafil	Q306	2N708	
C322	4.7/10V	Tantalum	Q307	2N929	
C323	1/35V	Tantalum	Q308	2N929	
C324	2 PF	Poly., Selected, Typical value shown	Q309	2N929	
C325	.001	Ceramic, Aerovox Cerafil	Q310	2N929	
C326	2.2/20V	Tantalum	Q311	2N863	
C327	.001	Ceramic, Aerovox Cerafil	Q312	2N780	
C327A	.001	Ceramic, Aerovox Cerafil	Q313	2N823	
C328	4.7/10V	Tantalum	Q314	2N799	
C329	.01	Ceramic, Glenco, Min-V-.01Z	Q315	2N863	
C330	.01	Ceramic, Glenco, Min-V-.01Z	Q316	2N863	
C331	Not used		Q317	2N929	
C332	.1/35V	Tantalum	Q318	2N708	
C333	.82/35V	Tantalum	Q319	2N708	
C334	6.8/20V	Tantalum	Q320	2N708	
C335	22/15V	Tantalum	Q321	2N708	
C336	6.8/35V	Tantalum	Q322	2N708	
C337	2.2/20V	Tantalum	R301	1000	
C338	.02	Ceramic, Glenco, Min-V-.02Z	R302	560	
C339	.001	Ceramic, Aerovox Cerafil	R303	910	
C340	6.8/6V	Tantalum	R304	10K	
C341	33 PF	Ceramic, Aerovox Cerafil	R305	24K	
C342	33 PF		R306	240K	
C343	33 PF		R307	Not used	
C344	33 PF		R308	33K	
C345	33 PF		R309	47K	
C346	33 PF		R310	3000	
C347	33 PF		R311	1800	
C348	33 PF		R312	3000	
C349	.01	Poly.	R313	33K	
C350	4.7/10V	Tantalum	R314	47K	
			R315	20K	
			R316	3000	
			R317	620	
			R318	3000	
			R319	20K	

Table B-III (Concluded)

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
R320	33K	Sensistor 1/8 w, 10% Selected, Typical value shown			
R321	62K				
R322	2000				
R323	270				
R324	3900				
R325	100K				
R326	39K				
R327	27K				
R328	3900				
R329	43K				
R330	680K	Sensistor, 1/8 w, 10%			
R331	110K				
R332	180K				
R333	51K				
R334	10K				
R335	3900				
R336	10K				
R337	24K				
R338	5600				
R339	15K				
R340	180	EKC 1% T2			
R341	1.0M				
R342	1.0M				
R343	39K				
R344	39K				
R345	24K				
R346	287K				
R347	560				
R348	43K				
R349	2000				
R350	6800				
R351	3000				
R352	8200				
R353	8200				
R354	30K				
R355	30K				
R356	82K				
R357	82K				
R358	560K				
R359	560K				
R360	12K				
R361	12K				
R362	150K				
R363	150K				
R364	150K				
R365	150K				
R366	1.0M				
R367	1.0M				
R368	300				
R369	390K				

Table B-IV
PARTS LIST, MODULE 4

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
C401	4.7/10V	Tantalum	C457	33	Ceramic, Aerovox Cerafil ↓
C402	75	Glass/Poly trimmer	C458	33	
C403	75	Glass/Poly trimmer	C459	100	
C404	6.8/35V	Tantalum	C460	100	
C405	Not used		CR401	FD300	
C406	Not used		CR402	FD300	
C407	100	Ceramic, Aerovox Cerafil ↓	CR403	FD300	
C408	100		CR404	FD300	
C409	100		CR405	FD300	
C410	33		CR406	FD300	
C411	33		CR407	FD300	
C412	100		CR408	FD300	
C413	33		CR409	FD300	
C414	100		CR410	FD300	
C415	33		CR411	FD300	
C416	100		CR412	FD300	
C417	33		CR413	FD300	
C418	100		CR414	FD300	
C419	33		CR415	FD300	
C420	100		CR416	FD300	
C421	33		CR417	FD300	
C422	100		CR418	FD300	
C423	33		CR419	FD300	
C424	100		CR420	FD300	
C425	33		CR421	FD300	
C426	100		CR422	FD300	
C427	33		CR423	FD300	
C428	100		CR424	FD300	
C429	33		CR425	FD300	
C430	100		CR426	FD300	
C431	33		CR427	FD300	
C432	100		CR428	FD300	
C433	33		CR429	FD300	
C434	100		CR430	FD300	
C435	33		CR431	FD300	
C436	100		CR432	FD300	
C437	33		CR433	FD300	
C438	100		CR434	FD300	
C439	33		Q401	2N929	Selected for high h_{FE} and low I_{CBO}
C440	100		Q402	2N929	
C441	33		Q403	2N929	
C442	100		Q404	2N799	
C443	33		Q405	2N708	
C444	100		Q406	2N863	
C445	33		Q407	2N708	
C446	100		Q408	2N863	
C447	33		Q409	2N863	
C448	100		Q410	2N708	
C449	33		Q411	2N929	Selected for similar V_{CES}
C450	100		Q412	2N929	
C451	33		Q413	2N929	
C452	100		Q414	2N929	
C453	33		Q415	2N929	
C454	100		Q416	2N929	
C455	33		Q417	2N929	
C456	6.8/6V	Tantalum	Q418	2N929	

Table B-IV (Continued)

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
Q119	2N929	Selected for similar V_{CES}	R434	1.2M	Selected, Typical values shown
Q120	2N929		R435	180K	
Q121	2N929		R436	910K	
Q122	2N929		R437	1.2M	
Q123	2N929		R438	680	
Q124	2N929		R439	1.0M	
Q125	2N929		R440	1.0M	
Q126	2N929		R441	1.2M	
Q127	2N929		R442	910K	
Q128	2N929		R443	68K	
Q129	2N929		R444	68K	
Q430	2N929		R445	910K	
Q431	2N929		R446	1.2M	
Q432	2N929		R447	1.0M	
Q433	2N929		R448	1.0M	
Q434	2N929		R449	1.2M	
Q435	2N929		R450	910K	
Q436	2N929		R451	68K	
Q437	2N929		R452	68K	
Q438	2N863		R453	910K	
R401	1000	IRC 1% T2 EKC 1% T2 EKC 1% T2	R454	1.2M	
R402	56.2K		R455	1.0M	
R403	16.2K		R456	1.0M	
R404	1000		R457	1.2M	
R405	200K		R458	910K	
R406	1.2M		R459	68K	
R407	15K		R460	75K	
R408	30K		R461	910K	
R409	5100		R462	1.2M	
R410	2700		R463	1.0M	
R411	2700	Ultronix 1% 15 PPM Selected, Typical value shown Ultronix 1% 15 PPM Selected, Typical value shown	R464	1.0M	
R412	100K		R465	1.2M	
R412A	12K		R466	910K	
R413	100K		R467	68K	
R413A	12K		R468	75K	
R414	100K		R469	910K	
R415	56K		R470	1.2M	
R416	560		R471	1.0M	
R417	18M		R472	1.0M	
R418	18M		R473	1.2M	
R419	9.1M	IRC 1% DCA IRC 1% DCA IRC 1% DCA IRC 1% DCA IRC 1/4% T2 IRC 1/4% T2 IRC 1/10% T9 IRC 1/10% T9 IRC 1/10% T9 IRC 1/10% T9	R474	910K	
R420	9.1M		R475	68K	
R421	4.3M		R476	91K	
R422	4.3M		R477	910K	
R423	2.2M		R478	1.2M	
R424	2.2M		R479	1.0M	
R425	1.1M		R480	1.0M	
R425A	1.1M		R481	1.2M	
R426	549K		R482	910K	
R427	549K		R483	68K	
R428	274K	Not used	R484	137K	
R429	274K		R485	910K	
R430	137K		R486	1.2M	
R431	137K		R487	1.0M	
R432	10M		R488	1.0M	
R433	Not used		R489	1.2M	
R433A	68K		R490	910K	
			R491	68K	
			R493	∞	

Table B-IV (Concluded)

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
R493	910K				
R494	1.2M				
R495	1.0M				
R496	1.0M				
R497	1.2M				
R498	910K				
R499	68K				
R4100	68K				
R4101	910K				
R4102	1.2M				
R4103	1.0M				
R4104	1.0M				
R4105	1.2M				
R4106	910K				
R4107	68K				
R4108	68K				
R4109	910K				
R4110	1.2M				
R4111	1.0M				
R4112	1.0M				
R4113	1.2M				
R4114	910K				
R4115	68K				
R4116	68K				
R4117	910K				
R4118	1.2M				
R4119	1.0M				
R4120	1.0M				
R4121	1.2M				
R4122	910K				
R4123	68K				
R4124	68K				
R4125	910K				
R4126	1.2M				
R4127	1.0M				
R4128	1.0M				
R4129	1.2M				
R4130	910K				
R4131	68K				
R4132	68K				
R4133	68K				
R4134	68K				
R4135	1.0M				
R4135A	1.2M				
R4136	1.0M				
R4137	910K				
R4138	910K				
R4139	20K				
R4140	470K				
R4141	110K				
R4142	18M				

Table B-V
PARTS LIST, MODULE 5

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
C501	39/10V	Tantalum	Q508	2N863	$\left\{ \begin{array}{l} (h_{FE} \text{ 10 at } 10\mu a) \\ (h_{FE} \text{ 10 at } 10\mu a) \end{array} \right\} \text{Match to } 10\%$
C502	.056/35V	Tantalum	Q509	2N863	
C503	1/35V	Tantalum	Q510	2N863	
C504	2.2/20V	Tantalum	Q511	2N863	
C505	.003	Ceramic, Glenco, Min-M-.003K	Q512	2N708	
C506	1/35V	Tantalum	Q513	2N863	
C507	6.8/6V	Tantalum	Q514	2N708	
C508	.33/35V	Tantalum	Q515	2N863	
C509	1/35V	Tantalum	Q516	2N863	
C510	2.2/20V	Tantalum	Q517	2N863	
C511	.33/35V	Tantalum	Q518	2N929	
C512	.0056	Ceramic, Glenco, Min-M-.0056K	Q519	2N2412	
C513	.01	Ceramic, Glenco, Min-M-.01K	Q520	2N863	
C514	.022	Ceramic, Glenco, Min-M-.022K	Q521	2N708	
C515	750	Glass, Selected, Typical value shown	Q522	2N929	
C515A	50	Glass, Selected, Typical value shown	Q523	2N929	
C516	1000	Ceramic, Aerovox Cerafil	Q524	2N2412	
C517	150	Poly Selected, Typical value shown	Q525	2N929	
C517A	15	Poly Selected, Typical value shown	Q526	2N2412	
C518	150	Poly	R501	56K	Selected, Typical value shown
C519	130	Poly	R502	9100	
C520	1/35V	Tantalum	R503	3900	
C521	.01	Ceramic, Glenco, Min-M-.01K	R504	300K	
C522	.01	Ceramic, Glenco, Min-M-.01K	R505	470K	
C523	.017/35V	Tantalum	R506	1.0M	
C524	.003	Ceramic, Glenco, Min-M-.003K	R507	91K	
C525	1/35V	Tantalum	R508	22K	
C526	2600	Poly	R509	68K	
C527	680	Poly	R510	130K	
C528	2800	Poly	R511	9100	Selected, Typical value shown
C529	2200	Poly	R512	180K	
C530	1800	Poly	R513	180K	
C531	.033/35V	Tantalum	R514	22K	
C532	22/15V	Tantalum	R515	47K	
C533	.0022	Ceramic, Glenco, Min-M-.0022K	R516	390K	
C534	Not used		R517	110K	
C535	.001	Ceramic, Aerovox Cerafil	R518	71.5K	
C536	1/35V	Tantalum	R519	100K	
C537	1/35V	Tantalum	R520	100K	IRC Carbon Film 1% ACI 1% 150 PPM ACI 1% 150 PPM EKC 1% 50 PPM IRC 1% T2 EKC 1% T2 IRC 1% 50 PPM IRC 1% 50 PPM IRC 1% 50 PPM EKC 1% 50 PPM
C538	6.8/6V	Tantalum	R521	470K	
CR501	FD300		R522	158K	
CR502	Not used		R523	130K	
CR503	FD300		R524	3.0M	
CR504	FD300		R525	3.0M	
CR505	FD300		R526	51.1K	
CR506	FD300		R527	130K	
Q501	2N2412		R528	51.1K	
Q502	2N780		R529	21.5K	
Q503	2N929	(h _{FE} 100 at 100μa)	R530	21.5K	
Q504	2N780		R531	130K	
Q505	2N929		R532	200K	
Q506	2N929		R533	20K	
Q507	2N929		R534	10K	
			R535	120K	
			R536	1.0M	

Table B-V (Concluded)

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
R537	39K				
R538	Not used				
R539	Not used				
R540	30K				
R541	620				
R542	1.0M				
R543	1.5M				
R544	1.8M				
R545	680K				
R546	680K				
R547	1.0M				
R548	100K				
R549	20K				
R550	220K				
R551	180K				
R552	9100				
R553	9100				
R554	10K				
R555	33K				
R556	2000				
R557	27K				
R558	13K				
R559	15K				
R560	Not used				
R561	10K				
R562	2400	Selected, Typical value shown			
R563	91K	Selected, Typical value shown			
R564	470	Sensistor, 1/8 w, 10%			

Table B-VI
PARTS LIST, MODULE 6

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
C601	1/35V	Tantalum	Q601	2N699B	
C602	1/35V	Tantalum	Q602	2N699B	
C603	1/35V	Tantalum	Q603	2N722	
C604	1/35V	Tantalum	Q604	2N910	
C605	6.8/35V	Tantalum	Q605	2N863	
C606	.02	Ceramic, Glenco Min-M-.02K	Q606	2N863	
C607	1000	Ceramic, Aerovox Cerafil	Q607	2N708	
C608	1/35V	Tantalum	Q608	2N708	
C609	1000	Ceramic, Aerovox Cerafil	Q609	2N929	
C610	1000	Ceramic, Aerovox Cerafil	Q610	2N929	
C611	1500	Poly.	Q611	2N929	
C612	1500	Poly.	Q612	2N708	
C613	5000	Poly.	Q613	2N708	
C614	330	Poly.	Q614	2N708	
C615	330	Poly.	Q615	2N708	
C616	56	Poly.	Q616	2N708	
C617	6.8/6V	Tantalum	Q617	2N708	
CR601	1N270		Q618	2N708	
CR602	1N270		Q619	2N708	
CR603	FD300		Q620	2N708	
CR604	FD300		Q621	2N722	
CR605	FD300		Q622	2N708	
CR606	1N754		Q623	2N929	
CR607	1N754		Q624	2N929	
CR608	FD300		Q625	2N929	
CR609	1N270		Q626	2N929	
CR610	1N270		R601	2000	1/2 W, 5%
CR611	1N270		R602	2000	1/2 W, 5%
CR612	1N270		R603	560	
CR613	1N270		R604	100K	
CR614	1N270		R605	27	
CR615	1N754		R606	27	
CR616	FD300		R607	15K	
CR617	FD300		R608	11K	
CR618	FD300		R609	510	Selected, Typical value shown
CR619	FD300		R610	∞	Selected, Typical value shown
CR620	FD300				
CR621	FD300		R611	27K	
CR622	FD300		R612	43K	
CR623	FD300		R613	240K	
CR624	FD300		R614	560K	
CR625	FD300		R615	200K	
CR626	FD300		R616	300K	
CR627	FD300		R617	200K	
CR628	FD300		R618	1.8M	
CR629	FD300		R619	180K	
CR630	FD300		R620	6.8M	
CR631	FD300		R621	620K	
CR632	FD300		R622	1.0M	
CR633	FD300		R623	1.0M	
CR634	FD300		R624	820K	
CR635	FD300		R625	5.6M	
CR636	FD300		R626	15M	
CR637	FD300		R627	33K	
CR638	FD300		R628	220K	
CR639	FD300		R629	470K	
CR640	FD300				

Table B-VI (Concluded)

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
R630	470K				
R631	220K				
R632	430K				
R633	470K				
R634	470K				
R635	220K				
R636	12K				
R637	300				
R638	100				
R639	100				
R640	36K				
R641	300K				
R642	36K				
R643	300K				
R644	1.8M				
R645	270K				
R646	120K				
R647	1.0M				
R648	1.5M				
R649	Not used				
R650	4.7M				
R651	3.3M				
R652	1000				
R653	2.7M				
R654	2.7M				
R655	2.2M				
R656	820K				
R657	560K				
R658	820K				
R659	1.0M				
R660	2.2M				
R661	820K				
R662	16K				

Table B-VII
PARTS LIST, MODULE 7

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
C701	6.8/6V	Tantalum			
C702	.01	Ceramic, Glenco Min-M-.01K			
C703	.003	Ceramic, Glenco Min-M-.003K			
C704	1/35V	Tantalum			
C705	.01	Ceramic, Glenco Min-M-.01K			
C706	.01	Ceramic, Glenco Min-M-.01K			
C707	.01	Ceramic, Glenco Min-M-.01K			
C708	56/6V	Tantalum			
C709	.01	Ceramic, Glenco Min-M-.01K			
C710	6.8/35V	Tantalum			
C711	100	Ceramic, Feed-through			
C712	2000	Ceramic, Feed-through			
C713	100	Ceramic, Feed-through			
C714	2000	Ceramic, Feed-through			
C715	100	Ceramic, Feed-through			
C716	100	Ceramic, Feed-through			
C717	2000	Ceramic, Feed-through			
C718	2000	Ceramic, Feed-through			
C719	2000	Ceramic, Feed-through			
C720	2000	Ceramic, Feed-through			
C721	2000	Ceramic, Feed-through			
C722	2000	Ceramic, Feed-through			
C723	2000	Ceramic, Feed-through			
C724	2000	Ceramic, Feed-through			
C725	2000	Ceramic, Feed-through			
C726	2000	Ceramic, Feed-through			
R701	22K				
R702	100K				
R703	270K				
R704	270K				
R705	270K				
R706	2000				
R707	Not used				
R708	270K				
R709	2000				
R710	2000				
R711	2000				
R712	10K				
R713	22K				
R714	390K				
R715	20K				
R716	1000				
R717	1000				
R718	470K				
R719	10K				
R720	1100				
R721	510				
L701	68 μ hy	ACDC, RFC-S-68			
L702	68 μ hy	ACDC, RFC-S-68			

Table B-VIII

Ref. No.	Value	Specifications	Ref. No.	Value	Specifications
C801	.01	Ceramic, Vitramon			
C802	.01	Ceramic, Glenco			
C803	.01	Ceramic, Glenco			
C804	470	Glass			
C805	39/10V	Tantalum			
C806	39/10V	Tantalum			
C807	200	Glass			
C808	2.2/20V	Tantalum			
C809	22/15V	Tantalum			
C810	22/15V	Tantalum			
C811	39/10V	Tantalum			
C812	22/15V	Tantalum			
Q801	2N1309				
Q802	2N929				
Q803	2N929				
Q804	2N929				
Q805	2N929				
Q806	2N863				
Q807	2N929				
Q808	2N929				
Q809	2N863				
R801	300K				
R802	43K				
R803	3300				
R804	30				
R805	5600				
R806	3300				
R807	43K				
R808	10K				
R809	10K				
R810	560				
R811	10K				
R812	15K				
R813	2200				
R814	1000				
R815	1000				
R816	15K				
R817	2200				
R818	24K				
R819	68K				

Table B-IX
INDUCTOR AND TRANSFORMER SPECIFICATIONS

Coil Number	Inductance (mh)	Core	Bobbin	Wire	Turns	Taps	Lead Colors	Comments and Notes
L101 L102 L103 L104, L107 L105, L106, L108 L109	1300 1160 1100 3370 3370 5950	53 N28 AL160 53 N28 AL160 53 N28 AL160 54 N28 AL250 54 N28 AL250 54 N28 AL250	1-section 1-section 1-section 1-section 1-section 1-section	46 CE 46 CE 46 CE 45 F 45 F 46 CE	2840 2670 2620 3600 3600 4820	None None None None 120 None	S-BN F-RD S-OR F-YL S-CN F-GR S-OR F-CN S-OR T1-YL F-CN S-BL F-VI	1600 cps low-pass filter 1600 cps low-pass filter 1600 cps low-pass filter 3.313 kc IF filter 3.313 kc IF filter 3.313 kc IF filter
L201 L202 L203 L204, L205, L206, L207 L208 L209 L210	89.1 82.8 76.4 88.3 600 75.6 43.1	52 N28 AL100 52 N28 AL100 52 N28 AL100 53 N28 AL160 53 N28 AL160 52 N28 AL100 52 N28 AL100	1-section 1-section 1-section 1-section 1-section 1-section 1-section	46 CE 46 F 46 F 41 F 45 F 46 F 44 F	943 909 872 735 1900 870 655	None None None 30 None None None	S-BN F-RD S-OR F-YL S-CN F-BL S-OR T1-YL F-CN S-OR F-CN S-CN F-VI S-CN F-WH	12.5 kc low-pass filter 12.5 kc low-pass filter 12.5 kc low-pass filter 26.5 kc IF filter 26.5 kc IF filter 14-25 kc output filter 14-25 kc output filter
L301 L302 L303 L304, L305 L306, L307 L308 L309	2.23 2.07 1.91 1.41 1.41 13.2 Sec. 0.90 Pri. 0.195	52 N28 AL100 52 N28 AL100 52 N28 AL100 54 N28 AL160 65 N28 AL250 53 N28 AL160 53 N28 AL160	1-section 1-section 1-section 2-section 2-section 1-section 1-section	36 HF 36 HF 36 HF 7/42 40/44 38 HI 34 F 39 F	149 144 138 92 73-1/2 289 73 34	None None None 7-1/2 3-1/2 None None 17	S-BK F-CN S-BK F-RD S-BK F-OR None None S-BK F-BN S-BN F-BK S-RD T-OR F-YL	100 kc low-pass filter 100 kc low-pass filter 100 kc low-pass filter 212 kc IF filter 212 kc IF filter 212 kc IF filter 53 kc output filter
L501 L502 L503	100 97.5 57.2	53 N28 AL160 52 N28 AL100 52 N28 AL100	1-section 1-section 1-section	43 HF 46 F 44 F	770 985 755	None None None	S-CN F-BL S-BK F-BL S-BK F-VI	30 kc output filter 12.5 kc output filter 12.5 kc output filter
L703	Pri. 750 Sec. 1500 Sec. 750 Sec. 150	65 N28 OL	1-section	37 HF 46 F 45 F 44 F	500 673 500 224	250 None None None	S-RD T-BN F-BK S-OR F-YL S-CN F-BL S-GR F-VI	Distribution Transformer
L801 L802	Pri. .4 μ h Sec. 40 μ h Pri. 48 μ h Sec. 36 Sec. 190 μ h	54 M25 A100 65 N28 OL	1-section	60/33 39 HF 60/33 32 HF 39	2 20 4 110 8	None None None None None	None S-VI F-BK None S-RD F-BN S-BK F-GR	Voltage Calibrate Inject Antenna Matching Transformer